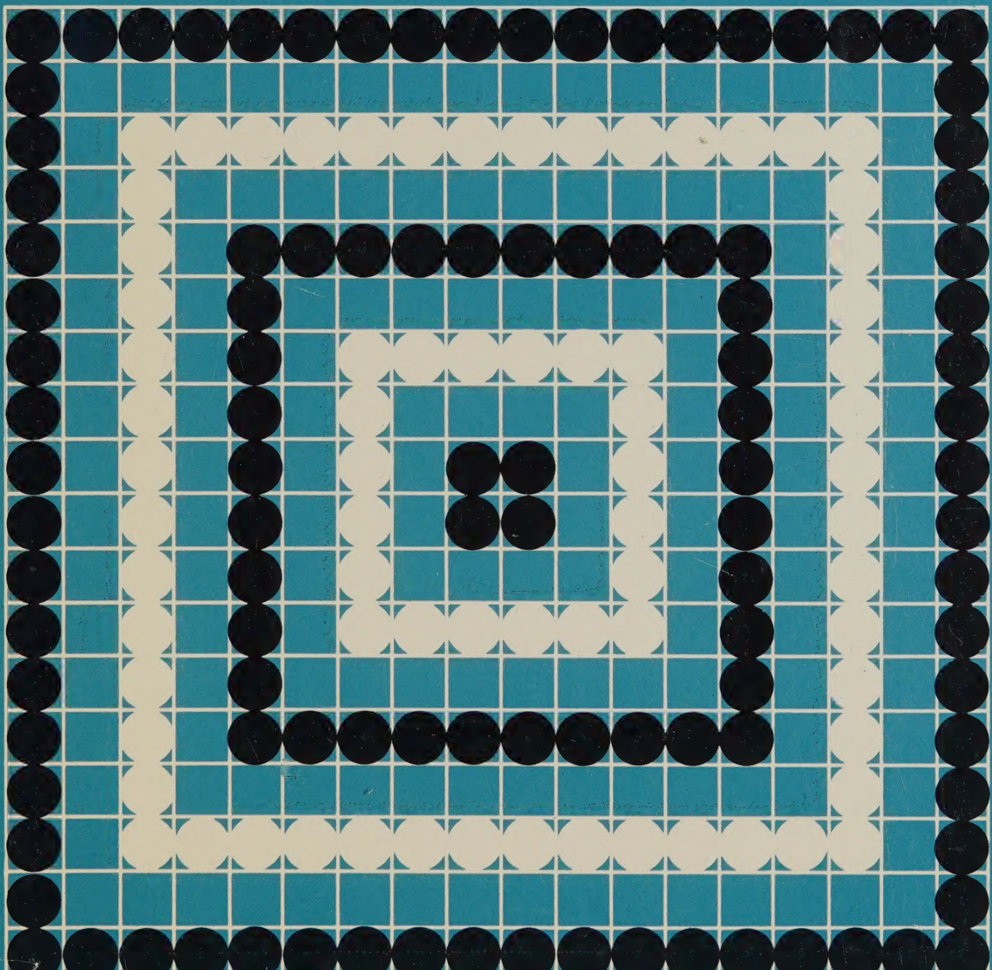
Transportation Energy Analysis Manual

1: Overview and Summary



The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM
Transportation Energy Analysis Manual

1: Overview and Summary

Published in Consultation with
The Municipal Transportation Energy Advisory Committee

by
The Transportation Energy Management Program (TEMP)
Transportation, Technology and Energy Division
Ontario Ministry of Transportation and Communications
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Preface

The purpose of the **Transportation Energy Analysis Manual (TEAM)** is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within their municipality. The Manual is organized into ten chapters, which outline the principal technical ways to conserve energy through transportation improvements.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is the crucial public-sector level because these decision-makers deal with the day-to-day activities of thousands of citizens residing within their municipalities. Energy conservation is an on-going, everyday affair, and the municipality is directly involved.

The **Transportation Energy Analysis Manual** consists of chapters on the subject areas listed below. These will be updated as considered necessary.

1. Overview and Summary
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Energy Program Management
10. Energy Analysis Methods

This chapter, **Overview and Summary**, surveys the range of activities and programs available for increasing the energy efficiency of transportation systems in Ontario municipalities.

Additional information on the Manual or on any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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1 Introduction

1.1 Overview

Since the turn of the century economic growth throughout the world, and in particular in the industrialized nations, has been based on the availability of cheap, abundant energy resources. Such resources have served as a catalyst to spur industrial growth, accelerate rises in the standard of living, and enhance the convenience and amenity of modern societies. Through the decade of the seventies, however, international events have served to accelerate the growing realization that energy resources, particularly petroleum, are finite and are no longer cheap. As a result, there has been a need to develop different views or approaches to society's allocation of its petroleum supplies.

Both Canada's and Ontario's growth have paralleled that of other industrialized nations. Based intially on cheap, abundant hydro-electric power, Canadian industries historically had a significant advantage. Since the 1950s, however, Canada's energy needs have been satisfied to a growing extent by petroleum energy. During the later seventies, Canada had to import a growing portion of its petroleum to satisfy its own needs. Also, like the rest of the world, Canada has been forced to reassess its energy position because of the need for energy security, and the negative impact escalating oil prices have on our balance of payments.

This Manual, prepared with the help of the Municipal Transportation Energy Advisory Committee, has been developed as part of the Energy Ontario Program. The aim of this program is to use energy resources more efficiently and effectively while maintaining the viability of Ontario's economic base. Transportation and energy concerns are being addressed through the direction and guidance of the Transportation Energy Management Program (TEMP), which is managed jointly by the Ministry of Transportation and Communications and the Ministry of Energy. Focused principally on municipal transportation energy conservation, the intent of this Manual is to guide municipalities to those actions which can reduce energy consumption, particularly of petroleum, both for the municipal corporation and the citizens whom it serves.

1.2 The TEAM Manual

The Transportation Energy Analysis Manual deals with all aspects of transportation-related energy consumption in built-up areas. It is intended to be a comprehensive reference that describes energy-conservation opportunities and measures, and presents data on impacts, experience, and implementation. It is not, however, a design manual. The technical details relating to the various measures will require reference to other sources and specialized studies.

The Manual will be revised periodically as additional information becomes available, as more experience with the conservation measures is gained, and as comments from the users of the document are assessed. The Manual will be distributed to all municipalities in Ontario with a population of over 5000, and is available to other agencies on request. Including this overview and summary section, there are ten chapters in the Manual. Six chapters deal with specific transportation categories, two focus on conservation program management, and a final chapter reviews energy consumption calculations and analysis methods. The subject of each chapter is as follows:

1. Overview and Summary
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Energy Program Management
10. Energy Analysis Methods.

2 Energy Background

2.1 World Energy Situation

During recent years, a growing portion of the world's energy supply has been contributed by petroleum. However, this trend is not expected to continue in the future. Because of production constraints, petroleum is projected to supply an ever-decreasing portion of world-wide energy requirements. As illustrated in Table 1.1, the use of other energy sources by the industrialized OECD nations is expected to increase over the next two decades, with oil's share falling from 49% in 1980 to 36% in the year 2000. As well, domestic production will likely account for a larger percentage of the required petroleum supply over this same period. Figure 1.1 shows graphically how this changing supply picture is expected to affect the demand for the major energy sources in the industrialized OECD countries.

Over this same period, crude oil prices have experienced rapid growth. As illustrated in Figure 1.2, the price of imported crude in Montreal has risen from $4.00/barrel in 1973 to $43.00/barrel in 1982. Because of the current softening of world oil prices, present estimates are that the Canadian price will reach the ceiling (75% of the world price) agreed to by the federal and Alberta governments in mid-1983, instead of 1986 as originally planned. The recent flattening of prices should not, however, lead to complacency, in view of the price volatility show in previous years.

Canada has accounted for a relatively stable 4 to 5% of world energy demand in the past and is expected to continue at this level. However, as depicted in Figure 1.3, Canada and the United States far outstrip other industrialized nations as measured by the ratio of energy consumed per

Table 1.1

OECD Primary Energy Supply*

Supply †	1980	1985	1990	2000
Domestic Production				
Oil ‡	4 906	4 789	4 451	5 009
Natural Gas	4 747	4 809	4 809	4 823
Coal	5 484	5 726	6 842	9 577
Nuclear	999	2 067	2 928	3 927
Hydro/Other §	1 757	1 915	2 136	3 307
Total	17 893	19 306	21 166	26 643
Net Imports				
Oil ¶	8 130	6 897	6 718	6 008
Natural Gas	296	579	1 137	1 723
Coal	235	296	392	689
Total	8 661	7 772	8 247	8 420
Total (Domestic + Imports)	26 554	27 078	29 413	35 063

Source: *World Energy Outlook*. International Energy Agency, 1982.

* Organization for Economic Cooperation and Development; figures given are for OECD's low-demand scenario.

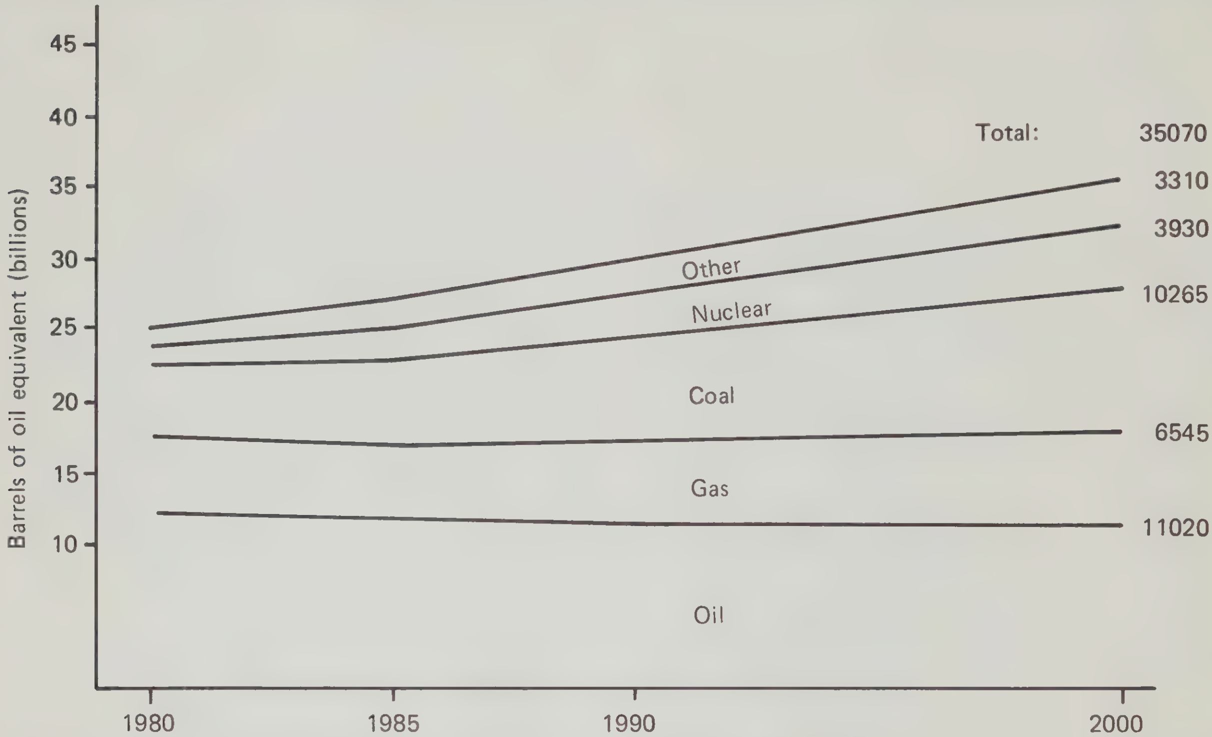
† In millions of barrels of oil equivalent

‡ Including natural gas liquids and synfuels

§ Including new and renewable sources of energy

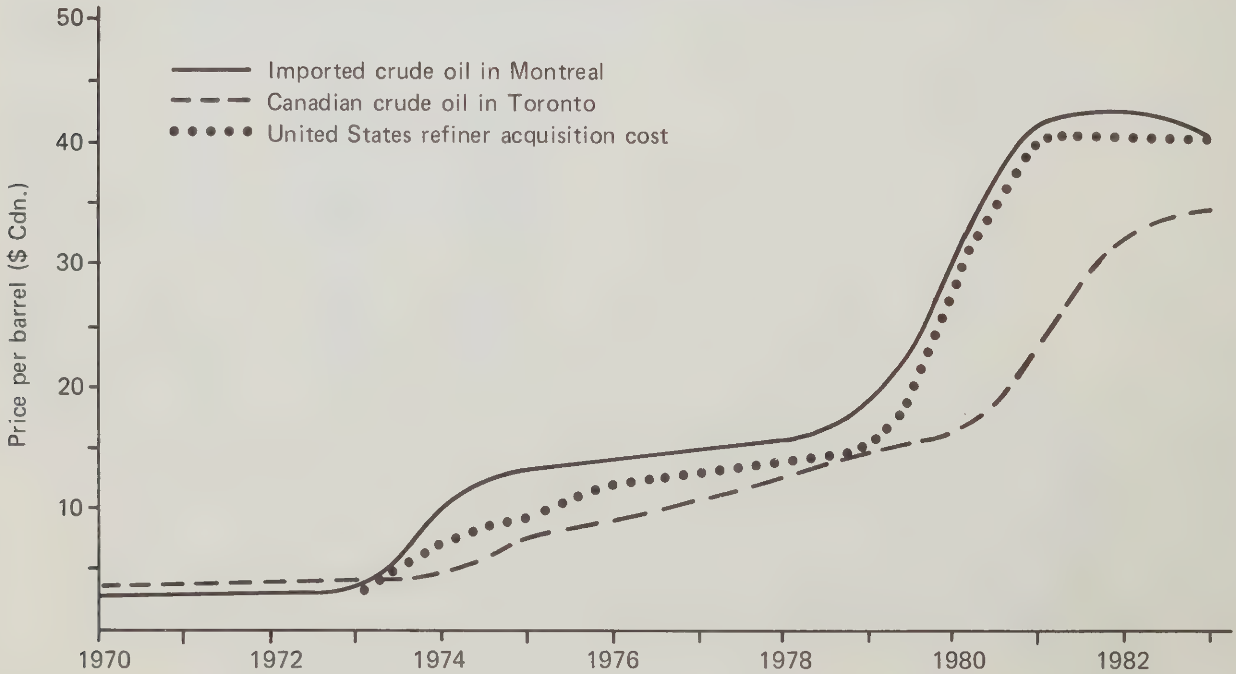
¶ Including bunkers and 1980 stock increases

Figure 1.1
OECD Primary Energy Demand*



SOURCE: *World Energy Outlook*. International Energy Agency, 1982.
* Organization for Economic Cooperation and Development; figures given are for OECD's low-demand scenario.

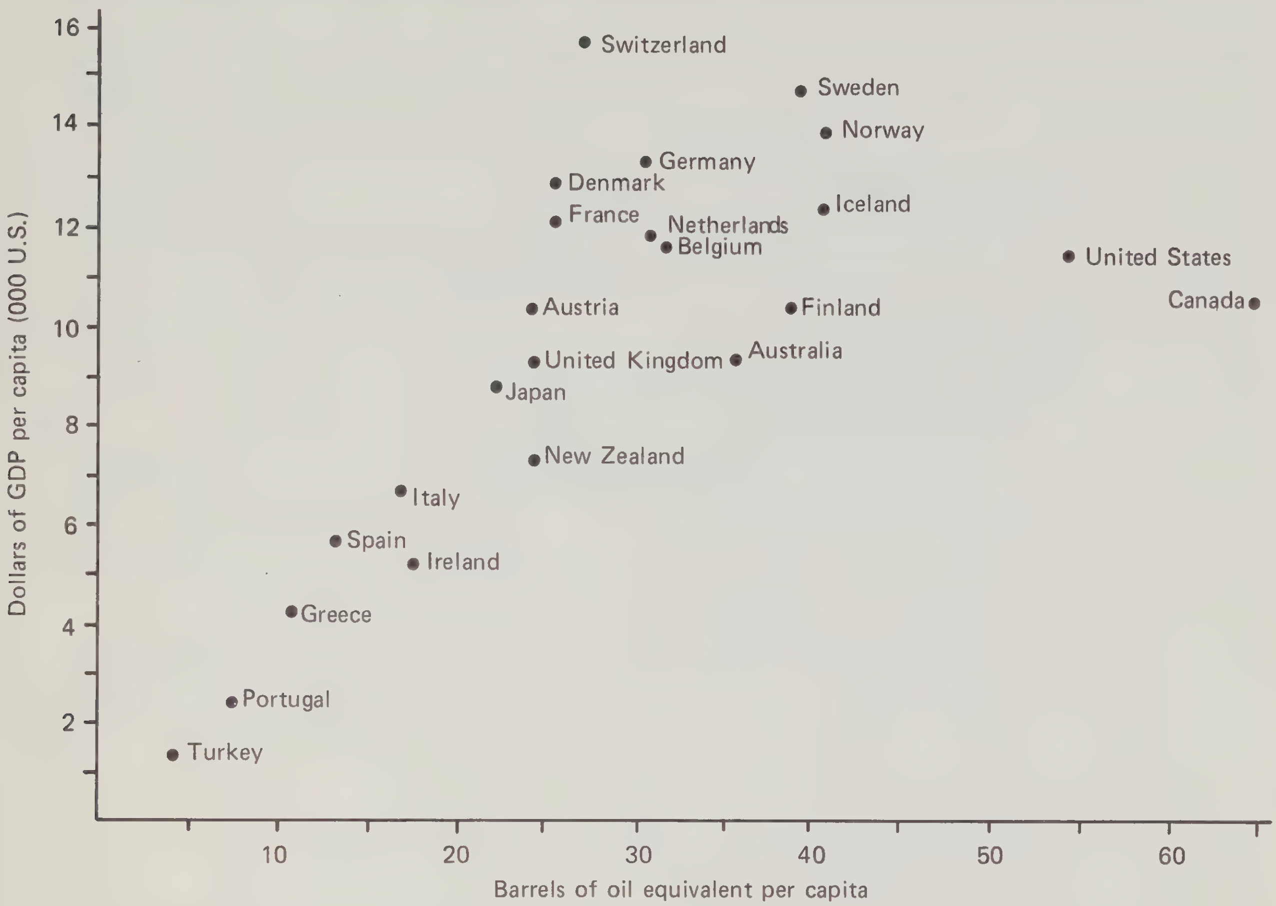
Figure 1.2
World, United States, and Canadian Crude Oil Prices



SOURCE: Ontario Energy Review

Figure 1.3

Primary Energy Consumption Per Capita Compared with GDP Per Capita, 1980*



SOURCE: *Observer*, March 1982

* Figure includes only countries belonging to OECD (Organization for Economic Cooperation and Development); GDP = Gross Domestic Product

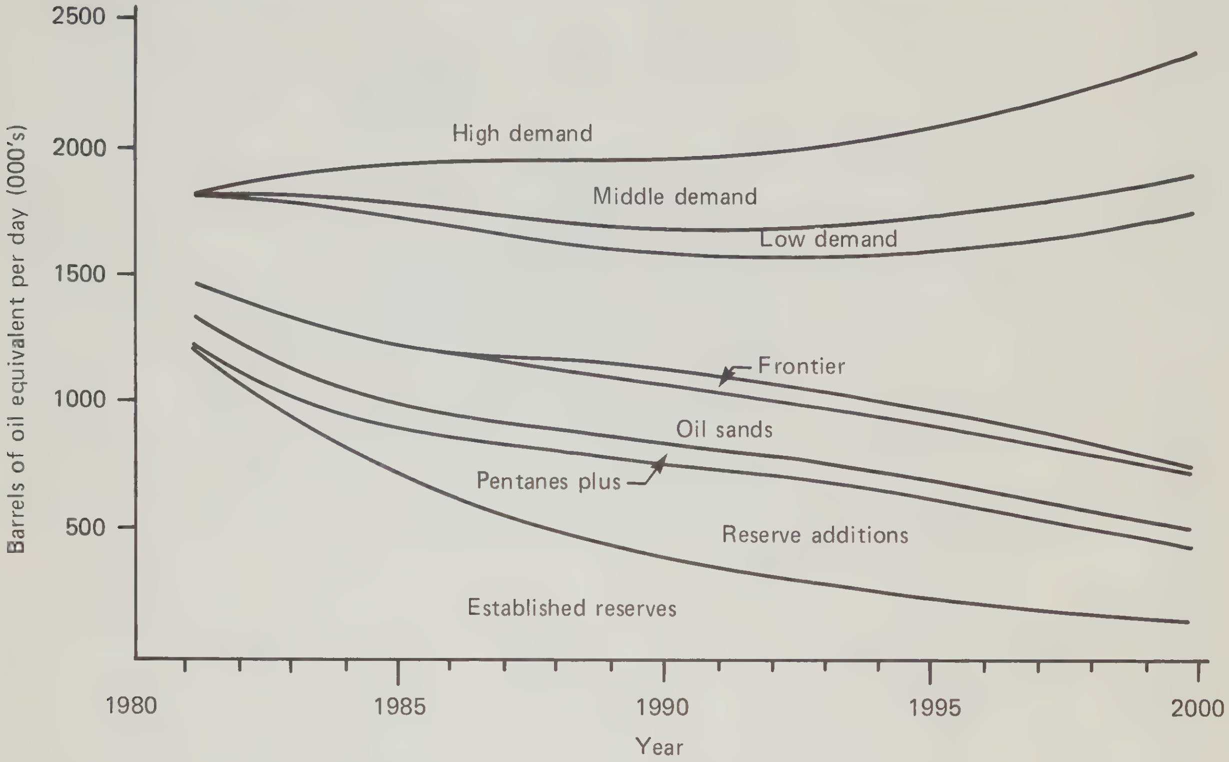
capita to gross domestic product per capita. In other words, other nations are more efficient than either Canada or the U.S. in terms of energy consumed per unit of gross domestic product.

At present, Canada is a net importer of petroleum products. Current estimates peg Canada's import dependence at 12%. This figure could, however, rebound to its previous level of 20% if the economy begins to grow again. Present estimates indicate an oil supply and demand scenario for Canada as depicted in Figure 1.4. Canada has set a target of attaining crude oil self-sufficiency by 1990, and this target is supported by Ontario.

2.2 Ontario's Energy Usage and Goals

Table 1.2 shows the breakdown of Ontario's anticipated energy consumption by source, through to the year 2000. Ontario imports most of its required energy, primarily from other parts of Canada. While it has become in recent years a net exporter of electricity, Ontario has almost no available resources of natural gas, petroleum, or coal. The province is, therefore, vulnerable to changes in energy supply and price caused by

Figure 1.4
Crude Oil and Equivalent Supply and Demand, Canada, 1980-2000*



SOURCE: National Energy Board, *Canadian Energy Supply and Demand 1980-2000*. Supply and Services Canada, June 1981.
* Base supply with low, middle, and high demand

events beyond its borders. Of the various energy sources the most sensitive to these changes is oil.

Table 1.2
Primary Energy Consumption, Ontario, 1970-2000

	1970	1975	1980	1990	2000
Oil	43%	40%	38%	29%	26%
Coal	20	14	14	14	14
Natural Gas	19	24	22	23	21
Hydro	16	14	12	12	11
Nuclear	—	4	12	19	26
Other	2	4	2	3	2
Total (BOE*)	411.3	476.7	558.1	600.9	709.9

SOURCE: Ontario Ministry of Energy
* Barrels of oil equivalent (millions)

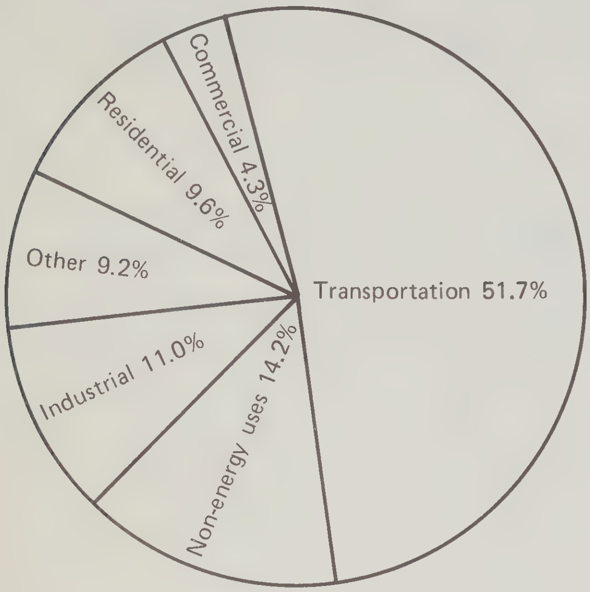
To the transportation sector, oil is especially important because almost all transportation fuel is currently derived from crude oil. As Figure 1.5 shows, transportation accounts for over half of provincial oil consumption. At current price levels, Ontario's annual oil bill is almost $6 billion. Needless to say, energy conservation in the transportation sector can yield significant benefits for all Ontarians. Indeed, it can have a major impact on the amount of money available for investment in the province.

Figure 1.6 breaks down provincial transportation energy consumption by mode. From this, it can be seen that auto and truck usage accounts for over 80% of the oil consumed in transportation. This is, therefore, a significant area for potential savings.

Specific targets for Ontario are to achieve an improvement in energy efficiency of 33% in passenger transportation and 20% in freight transportation between 1980 and 1995. These targets are measured in terms of fuel consumption per person-kilometre and per tonne-kilometre, respectively.

Figure 1.5

Total Oil Consumption, Ontario 1981



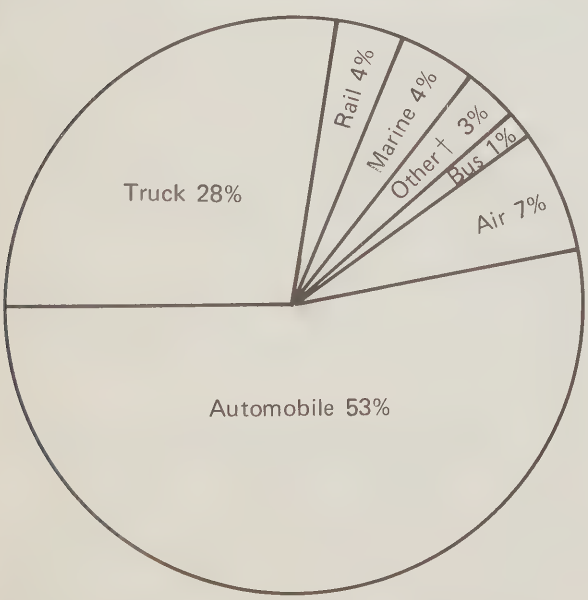
Total: 191 million barrels of oil equivalent/year

SOURCE: Statistics Canada and Ontario Ministry of Energy

Note: Other — refinery use and electricity generation; Non-energy — petrochemical feedstocks, lubrication oils and grease, asphalt, etc.

Figure 1.6

Transportation Energy Consumption, Ontario 1981



Total: 271 000 barrels of oil equivalent/day

SOURCE: Ontario Ministry of Energy

† Commuter, rail, subway, streetcar, trolley, school bus, motorcycle, leisure vehicles, off-road vehicles, farmers' trucks and tractors

3 Transportation Energy Management

3.1 Ontario's Transportation Energy Management Program (TEMP)

The Transportation Energy Management Program (TEMP) is the Ontario Government's program for reducing Ontario's oil dependency in the transportation sector. Established in 1977 as a joint program involving the Ministry of Transportation and Communications (MTC) and the Ministry of Energy (MEny), Phase I involved the development of an action plan and Phase II was a series of research and demonstration projects. Currently, the program is in Phase III — a marketing mode, with several transportation energy-saving products and services positioned for delivery to various transportation user groups within Ontario. The program is administered by MTC in cooperation with MEny and is part of Energy Ontario.

While the overall provincial goal is to increase the energy efficiency of passenger transportation by 33% and of freight transportation by 20% between 1980 and 1995, the goal for TEMP is a savings of 10% in fuel usage over the conservation expected from the average fuel economy standards of vehicles. TEMP intends to reach its goal by 1985 through a series of initiatives with the following objectives:

- improving the efficiency of transportation technology;
- improving the efficiency of transportation operations;
- using more efficient modes;
- developing and promoting alternatives to oil;
- reducing travel requirements.

The main marketing thrusts of the TEMP program and the various initiatives contained within each are outlined in the following sections. Information on any program can be obtained from the TEMP office, (416) 248-7296.

3.2 Municipal Transportation Energy Management

The aim of this program is to increase the energy efficiency of transportation systems in Ontario municipalities through a program of information and demonstration. The program is directed at municipal political leaders and staff through a variety of mechanisms, including various municipal associations and a special energy coordinating body established by the province called the Municipal Transportation Energy Advisory Committee (MTEAC). Initiatives taken within this program include the following:

- publication of an MTEAC newsletter for distribution to all municipalities on a quarterly basis;
- dissemination of the state-of-the-art municipal Transportation Energy Analysis Manual (TEAM) to Ontario municipalities;
- completion of a review of traffic-management energy impacts, to document the energy costs of various signing and signal policies and to show the benefits of innovative traffic-management strategies;
- initiation and promotion of a municipal driver training program;
- initiation of a fleet-management demonstration project in an Ontario municipality;
- review of preferential treatment for high-occupancy vehicles (HOVs) to ascertain the necessary conditions for their implementation, assess the feasibility of their introduction on Ontario municipal and provincial roads, and develop guidelines for their use;
- support for municipal energy-management reviews: Hamilton / Wentworth has reviewed and is implementing some promising transportation-management strategies and Metro Toronto has completed the first phase of an energy-management study documenting energy intensity of modes, with a second phase now under way, involving a major policy review.

3.3 Ridesharing

The aim of this program is the promotion of ridesharing throughout Ontario in settings where public transit is not a viable option. At the moment there are two marketing thrusts. One involves the efforts of the TEMP Share-A-Ride Program which is focused on the establishment of carpooling and the promotion of the concept of company-sponsored and privately operated vanpools. This program is primarily aimed at large employers who will purchase their own vans and operate vanpools for their employees. It is marketed by means of presentations and technical assistance to large companies. Some municipalities have jointly participated with TEMP in this activity. Some 115 vanpools have been established by large companies.

The second marketing thrust is being undertaken by the Ontario Van Pool Organization (OVPO) and

is aimed at providing third-party vanpools on a profit-making basis. OVPO provides van and vanpool management services to those who wish to rideshare. OVPO is aiming its marketing efforts at Ontario Government employees and individuals who are self-employed or who work in companies that do not offer a vanpool program.

Initiatives under way, coordinated by TEMP, include:

- a carpool and vanpool demonstration program which involves marketing vanpools to large companies, presenting car and vanpooling displays in exhibitions; and publicizing carpool parking lots located near freeways;
- building carpool parking lots on major roads near cities (there are now about 1 500 spaces in place);
- assessing the feasibility of establishing comprehensive ridesharing information services for the public (carpool and vanpool marketing, transit) at the municipal level.

3.4 Trucksave

Trucksave was enacted with the overall objective of improving by 20% the efficiency of fuel use of Ontario's medium and heavy trucks by 1995. The program is directed by a twelve-member committee representing government, private industry, and trucking organizations. The program is marketed through existing trucking organizations, special seminars, conferences, and Trucksave mail-outs. Other activities include:

- an over-the-road fuel economy challenge to inspire truck drivers to compete on fuel efficiency;
- publication of the "Trucksave News" newsletter;
- production of an 8-booklet manual which deals with spec'ing fuel-efficient trucks;
- distribution of printed information, slide shows, and a film to members of the trucking industry.

3.5 DriveSave

The objective of this program is to improve the fuel economy of Ontario's drivers. It is aimed at light-vehicle fleet drivers, beginner drivers, and the general driving population. DriveSave is directed by a fleet advisory committee of fourteen representatives from fleets and municipal governments who, together with eleven more representatives, work in five subcommittees to promote and administer driver conservation programs. DriveSave is responsible for:

- initiation of an information program to encourage energy-efficient auto purchase and ownership practices;
- production of a film about fuel-efficient driving techniques to be shown to beginner drivers and fleet managers;
- publication of a newsletter which is sent to fleet managers and driver educators.

3.6 Alternative Fuels Promotion

The Government of Ontario has launched a comprehensive Alternative Transportation Fuels (ATF) Program with the objective of reducing the transportation sector's dependence on petroleum fuels from 100% to 90% by 1995. The program involves all aspects of alternative fuels, from supply to utilization, and is coordinated by the Ministry of Energy.

The ATF Program is concerned with research into alternative fuels for Ontario's transportation sector and with limited fleet testing of them. Fuels under active investigation include propane, natural gas (liquefied and compressed), methanol and ethanol (as straight fuels and as blends), and hydrogen. Facilities used in these investigations include universities, private industry, the Ontario Research Foundation, The Urban Transportation Development Corporation (UTDC), and Ontario Government fleets and equipment. Projects currently under way involve natural gas, propane, hydrogen, a multi-fuel engine, and the generation of informational material on the ATF program.

3.7 Teleconferencing

The aim of teleconferencing is to reduce the need for business travel. In effect, it substitutes a small amount of electrical energy (used for telecomunications) for a much larger amount of oil (used for travel). Initial work has proven the feasibility of the concept in a demonstration within MTC linking its Downsview headquarters with its four regions and Queen's Park. Efforts are now focused on the following initiatives:

- promotion and demonstration of teleconferencing within the Ontario Government and private sector;
- assistance in the implementation of teleconferencing within large private-sector corporations;
- assistance in product development.

3.8 Program Coordination and Development

Work in this area is aimed at the coordination of Ontario activities with those under way elsewhere and the establishment of new energy-conservation initiatives for transportation. Activities included in this area are as follows:

- assessment of transportation energy activities under way in the Canadian federal government and in the U.S. government;
- review of the impact of petroleum price increases on the demand for transportation fuels and services in the U.S;
- review of incentives to promote public acceptance of fuel-efficient autos.

4 Energy Management Measures

4.1 Overview

Four basic strategies summarize the various transportation energy management measures which are available for municipal-level implementation. These strategies are ranked according to their ability to make more effective use of energy resources.

- Encouraging shorter vehicle trips or non-vehicular trips (i.e., walking, cycling) is the most direct and efficient way to reduce energy consumption in the transportation sector.
- The second highest potential energy saving is realized through the design and maintenance of more efficient transportation vehicles through the more efficient construction and maintenance of transportation infrastructure.
- The third strategy is to increase load factors or ridership, making energy consumption more efficient on a passenger-kilometre basis (for either transit, carpooling, or vanpooling).
- Finally, improving the operational efficiency of the individual transportation modes (through smoothing vehicular flow, reducing circuitous routing and scheduling, and other similar techniques) can improve the overall energy performance of the transportation system.

The measures described in the various chapters of this Manual relate to these strategies. Some chapters may emphasize one strategy, but a municipality's energy-conservation program should attempt to apply all appropriate opportunities in a comprehensive short-term and long-term plan.

The following sections summarize the major energy management measures which are coverd in greater detail in the corresponding chapters in the TEAM Manual.

4.2 Street-System Operation

There are four categories of measures designed to increase the operational and energy efficiency of the existing street system, which are discussed in detail in TEAM Chapter 2.

Traffic Flow Improvements

Measures that smooth the flow of traffic by reducing stops and delays help reduce vehicular energy consumption. These measures are not new to traffic engineers, having all been used in the past to reduce road congestion. Energy conservation is now another major benefit that can justify their implementation. They include:

- signal timing and coordination,
- downsigning,
- one-way streets,
- turning lanes and restrictions,
- bus bays,
- reversible lanes,
- improved signing,
- additional capacity at points of system constraint,
- on-street parking restrictions,
- freeway traffic management.

Preferential Treatment for High-Occupancy Vehicles (HOVs)

High-occupancy vehicles are vehicles that carry more than one person. A transit vehicle carrying many passengers is the most common form of HOV; a vanpool is an increasingly common form; carpools can be considered as HOVs for some applications.

Preferential treatment for HOVs is a direct attempt to give priority to the movement of multiple-occupant vehicles in preference to single-occupant ones. It can be provided through the use of HOV lanes, traffic-signal controls, and preferential parking. These tactics all help to reduce travel time for HOVs and to improve the service level of transit in particular. Such improvements enhance the people-moving productivity and energy efficiency of the street system.

Bicycling Facilities

The bicycle is the most energy-efficient urban transport mode. If bicycle ridership for purposes other than recreation can be encouraged, vehicles will be removed from the roadway and energy consumption thus reduced. Measures that encourage bicycle travel include:

- provision of bikeway systems (separate or shared);
- provision of bicycle storage facilities (downtown and at transit stops in particular);

- distribution of bikeway maps;
- revision of intersection regulations and design;
- administrative support actions (registration service, safety programs, promotional events).

Pedestrian Facilities

Obviously, walking as a travel mode in itself has limited energy saving potential because it can only replace more energy-intensive modes for short trips. However, in conjunction with transit, pedestrian facilities (at both the home and destination end of trips) can play a significant role in shifting travel patterns to nore energy-efficient modes.

4.3 Transit Service

Transit system improvements aimed at attracting new riders and increasing the energy efficiency of transit operations are outlined in TEAM Chapter 3.

Increasing Ridership

Increasing transit ridership reduces the number of vehicles sharing the road and increases the capacity of the travel corridor. This shift in travel mode has significant impacts and can be facilitated using a combination of appropriate measures, including:

- reducing travel time through transit service restructuring (e.g., minimizing need to transfer, providing limited stop service);
- reducing travel time by improving the flow of transit vehicles (e.g., introducing "transit-only" streets);
- introducing alternative fare packages such as monthly passes;
- reducing passenger wait time by introducing a computerized transit information system;
- increasing ridership through improved transit marketing;
- incorporating transit orientation into land use planning (e.g., appropriate street-system design for new sub-divisions, higher density areas along transit corridors).

Raising Efficiency

The introduction of fleet operations techniques to increase the energy efficiency of transit operations can result in significant cost savings. Techniques include:

- using the best size and type of vehicle for the job (e.g., small buses, articulated buses);
- improving the maintenance and operation of vehicles (e.g., energy-efficient driving habits and maintenance checks);
- improving energy use in storage and maintenance facilities;
- using alternative fuels (e.g., propane for small buses, electric trolley buses).

4.4 Ridesharing

One of the cheapest and most effective methods of saving energy is to increase the occupancy of vehicles on the road. Public transit is the major mode for high-occupancy vehicles. However, other forms of high occupancy can supplement transit service. Carpooling, vanpooling, and paratransit offer flexible and low-cost mechanisms for increasing vehicle occupancy and hence reducing energy consumption. The ridesharing options are explored in TEAM Chapter 4.

Role of Municipalities

With a minimum of staff time and costs, municipalities can play valuable coordination roles in implementing ridesharing programs. Municipalities interested in taking advantage of the benifits accruing from these programs can undertake the following steps:

- appoint a municipal ridesharing coordinator;
- conduct a local ridesharing market survey;
- implement ridesharing for municipal employees;
- stimulate and support ridesharing programs by other major employers;
- develop third-party vanpooling programs;
- promote and support area-wide carpooling;
- provide paratransit services in fringe areas (e.g., subscription bus service, contract vans, shared-ride taxi service);
- provide incentives (e.g., park-and-ride lots, reserved lanes, priority access, subsidized parking).

4.5 Travel Demand Management

Reducing the number and length of trips and leveling out the peaks in the remaining travel demand are major ways in which energy consumption can be reduced. The various actions which can be taken to manage travel demand are covered in TEAM Chapter 5. These measures are extremely cost effective (requiring little capital investment) but, by nature, have long term paybacks.

Land-Use Planning

The basic tenet of energy-conscious land-use planning is that energy efficiency will result when land-use activity is concentrated. Some of the measures being used by municipalities to implement such planning are:

- increase residential density through infilling and building compact housing;
- improve balance of people and jobs in communities through mixed-use zoning;
- encourage multi-use building developments;

- concentrate new development along transit corridors;
- street-system design to facilitate transit service and bus-route access by pedestrians.

Alternative Work Schedules

Alternative work schedules spread peak transportation demand over a longer time period, thereby enhancing the efficiency of the street and transit systems. Energy savings are achieved by reducing stops and delays, and smoothing the flow of traffic. Capital savings are achieved by postponing the need for new transportation facilities.

The major techniques for changing work schedules are:

- *staggered work hours* — specific work periods offset by 15 to 30 minutes assigned to groups of the total work force;
- *flexible work hours* — peak arrival and departure times spread out by allowing workers to choose their own work period;
- *compressed work week* — people shorten their work week to four days by working longer hours each day.

Parking Management

Modifying the availability and price of parking can significantly reduce travel demand by automobiles. Rather than just diverting trips to another destination, the measure will result in a shift in mode of travel. Parking management measures include:

- increasing the cost of parking to encourage transit usage, especially for work trips;
- reducing the availability of parking space to force more use of transit;
- providing preferential parking to HOVs, using supply and cost measures, as a factor in generating a shift in the mode of travel.

Auto-Restricted Zones

Auto-restricted zones involve the restriction of general-purpose automobile travel in a specific area of the city, such as the Central Business District. Auto restrictions may be in place for 24 hours, for peak periods, or for off-peak periods, depending on the purpose and objective of the restrictions. The intent is to restrict travel in the zone specifically and to discourage auto travel in general. The objective of these measures is to cause people either to shift to transit modes that penetrate the zone or to utilize non-vehicular modes, such as pedestrian travel, for specific segments of their trip.

4.6 Municipal Fleet Management

The primary goal of fleet management is to minimize overall operating costs for the required workload. Energy cost-saving is an important element of this goal. Techniques that fleet managers can use to reduce energy costs are detailed in TEAM Chapter 6.

Conservation Measures

Basic to any energy conservation program is an information system that reports fuel consumption for every vehicle in the fleet. Once this system is established and the data are available, managers can identify opportunities, set priorities, and measure progress.

Measures that have proven effective in reducing fleet energy energy costs include:

Dieselization — Diesel engines are more fuel efficient than gasoline engines. The capital cost is higher, but reduced maintenance and lower fuel costs are the offsetting benefits.

Alternative Fuels — Use of a fuel that is not petroleum based is very significant in reducing oil consumption and fuel costs. At present, propane is the most viable option.

Vehicle Resizing — Both the reduction and the increase of new vehicle size can lead to significant fuel conservation in the movement of materials and personnel.

Fuel-Saving Options and Devices — The judicious application of certain equipment options can improve vehicle efficiency. Proven items include radial tires, drag-reducing devices, improved engine lubricants, thermostatically controlled radiator fans and shutters, appropriate transmission and axle ratios, tag axles, and lightweight bodies.

Vehicle Maintenance — Productivity can be improved by reducing the amount of non-productive travel through route design.

Driver Training — Fuel-efficient driving techniques can save municipalities up to 10% in fuel costs and can be included in regular driver-safety training programs.

4.7 Road Construction and Maintenance

Opportunities to conserve energy in municipal road construction and maintenance exist in two major areas: reductions in vehicle fuel consumption and the increased use of less energy-intensive construction materials and processes. The measures a municipality can use to achieve energy savings in these areas are discussed in TEAM Chapter 7.

Construction Methods

It has been suggested that the relaxation of geometric design standards, in particular the reduction of lane and shoulder widths, could lead to significant energy savings. However, the associated impacts on traffic safety and capacity and the lack of research in support of this measure eliminate it from consideration at this time. In addition, measures that do not appear to offer significant energy savings include: the use of paved shoulders, a reduction in mass-haul distances, and the substitution of portland cement concrete for asphalt concrete.

The following measures in municipal road construction and practice are believed to offer the greatest potential for energy conservation:

- *Recycling of asphalt pavement*. This measure has been recognized as the most promising opportunity. It was introduced into MTC operations in 1979 and in the following three years over 2.2 million tonnes of recycled hot mix were laid, with associated cost savings of $12.5 million.
- *Use of asphalt binder substitutes (e.g. sulphur)*. It has been proven that sulphur is a practical material to use in combination with asphalt cement. Its usage will depend, however, on its price compared with that of asphalt cement. Other substitutes, such as wood lignin and cellulosic materials, are still in the research stage.
- *Increased use of emulsified asphalt*. There are significant energy savings where emulsions are substituted for cutback asphalt, in particular for asphalt bases. Again its future usage depends on its price compared with that of asphalt cement.
- *Improvement of asphalt concrete production process*. The energy efficiency of the mixing process can be improved by the increased use of drum mixing and by improved procedures for heating and drying aggregate.
- *Improvement of fuel efficiency in road construction and rehabilitation*. It has been estimated that there could be significant fuel savings if contract sizes were increased, energy management plans utilized, and driver training emphasized in the contractors' operations.

Road Maintenance

In the area of road maintenance, the following measures offer possibilities for reduced fuel consumption:

- *Reduced inspection and patrol*. The patrol frequencies may be reduced by requesting municipal staff from other departments who travel the roads to regularly report on routing items requiring maintenance.
- *Reduction of roadside maintenance*. The frequency of minor maintenance activites (e.g., grass cutting, minor repairs, and painting) may be reduced or such activities undertaken jointly with municipal staff from other departments.
- *Reduced winter maintenance*. This activity can consume the largest portion of the total energy used in maintenance. Without significantly lowering levels of service for sanding, salting, or snowploughing (which could lead to increased accident costs and fuel consumption), municipalities can achieve fuel savings by optimizing equipment routing, using fuel-efficient equipment (e.g., extra wide snowplough blades), and using snowfencing of improved design.

The best opportunity for fuel savings in maintenance operations, however, seems to lie in the area of maintenance fleet management. Individual measures include driver training programs, energy-use reporting, dieselization, and use of alternative fuels.

5 Planning, Management and Evaluation

5.1 Overview

In working towards energy-conservation objectives, the manner in which measures are implemented is of equal importance to the measures themselves. Only by taking a comprehensive management approach, incorporating adequate program planning and evaluation, will major results be achieved. Planning for a ''worse case'' scenario should form part of this approach as well.

5.2 Contingency Planning

Few would argue that the supply of petroleum products is as secure as one would like. If an oil shortage were to occur, for whatever reason and duration, the primary responsibility for allocating available petroleum would rest with the federal government. Federal allocation mechanisms, the Ontario Government's supporting role, and the range of actions municipal governments would be called upon to implement are all discussed in TEAM Chapter 8.

Developing a Municipal Plan

The 1979 Mississauga train derailment demonstrated how preparedness can mitigate the effects of an emergency situation. The development of a municipal plan of action to cope with an oil shortage is only prudent.

Some of transportation-related roles municipal governments would be expected to undertake during a fuel shortage include:

- keeping its own fleet operating to provide needed services such as snowploughing and garbage collection;
- providing additional public transit to allow an increase number of people to leave their cars at home;
- helping form carpools and vanpools;
- calling for the implementation of alternative work schedules to level peak travel demand.

Obviously, in order to provide the firm leadership and orderly control which would be required, municipalities should begin now to develop their own contingency plan. Some of the best preparation is the implementation of a comprehensive energy-management program.

5.3 Municipal Energy Program Management

Management of energy is the same as the management of other municipal functions. It involves organizing manpower and resources, directing their application, and monitoring progress towards meeting objectives. Methods municipalities can use to implement comprehensive enrgy conservation programs are covered in TEAM Chapter 9.

A Management Framework

The accumulated experience of Ontario municipalities indicates there are certain ingredients necessary for a successful energy-management process.

- Obtain a strong commitment for energy conservation from council and senior staff.
- Assign responsibility for program management. Energy coordinators should be assigned (preferably a senior administrative officer or a councillor) and energy committees established.
- Set goals and objectives. These should be numerical and measurable to the greatest extent possible.
- Identify opportunities for energy conservation. The work of other cities and agencies can be helpful in this task.
- Establish current energy usage. This data would be a measure of fuel characteristics in your municipality, but studies and information from other sources can be helpful also.
- Select energy-conservation measures for implementation. Assign priorities and involve others in implementation.
- Monitor the results. This activity will indicate how well the plans are working, and it provides data that can be published and used to generate more support for the overall program.

5.4 Energy Analysis Methods

A critical step in all energy-conservation measures is the evaluation of the amount of energy saved. In some cases this evaluation can be done after a measure is in place. However, a more likely situation is that an estimate of savings is needed to

determine if action is justifiable. Energy analysis methods are detailed in TEAM Chapter 10.

Energy savings will normally come in one of three forms. The first is the energy saved as a result of a vehicle trip being eliminated — either a shift of mode from car to transit or the complete elimination of a trip. The second is the result of more efficient travel — usually travel time reduced through the elimination of stops and congestion on the streets. The third is the improved efficiency achieved through the use of different load characteristics, vehicle equipment, or fuel types.

In order to adequately support the planning and implementaton of appropriate and effective energy-management measures, the municipality should:

- develop in-house expertise in energy analysis methods;
- standardize energy analysis procedures and the data collection systems required to support them;
- formalize energy impact assessment as a component of the municipal planning process.

6 Conclusion

Transportation swallows over half of all the oil consumed in Ontario, at an annual cost of over $3 billion. These compelling economics, together with concerns about the security of supply, have put energy conservation in the transportation sector high on the list of Ontario government priorities.

While there is considerable scope for oil savings in inter-city transportation, it is transportation within municipal boundaries that offers the most immediate opportunies for major reductions. Because of greater travel density and choice of travel modes in our cities and towns, significant reductions in oil consumption can be achieved relatively quickly — especially when a comprehensive energy management approach is taken.

With fully 35% of Ontario's transportation energy used for travel in built-up areas, it is clear that the implementation of appropriate municipal transportation initiatives is an essential component of Ontario's energy-conservation program. But there are other compelling reasons for municipalities to implement these measures as well. In addition to improving safety and significantly reducing noise and air pollution levels, energy efficient transportation systems reduce travel delay and save dollars. Money that would have left Ontario to buy oil can, instead, be kept in the local economy. Money that would have been needed to build costly new roadway capacity can be saved and applied to other municipal services. In short, energy conservation in municipal transportation is not only good for Ontario as a whole — it is also good for every town and city in the province.

This Manual provides Ontario municipalities with the state-of-the-art information and tools they need in order to implement comprehensive transportation energy-management programs.

Ontario

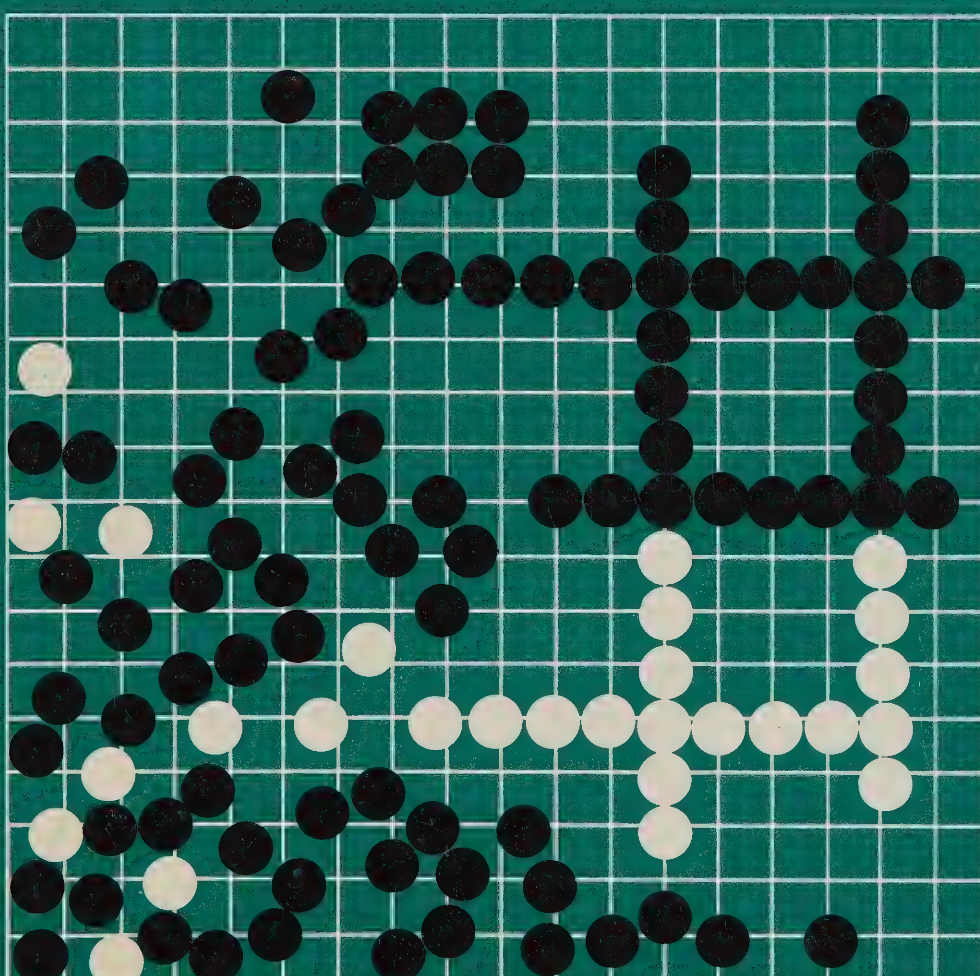
Ministry of
Transportation and
Communications
Hon. James W. Snow
Minister

Ministry
of
Energy
Hon. Robert Welch
Minister

Energy
Ontario

Transportation Energy Analysis Manual

2: Street-System Operation



The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM
Transportation Energy Analysis Manual

2: Street-System Operation

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Preface

The purpose of the **Transportation Energy Analysis Manual (TEAM)** is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within their municipality. The Manual is organized into ten chapters, which outline the principal technical ways to conserve energy through transportation improvements.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is the crucial public-sector level because these decision-makers deal with the day-to-day activities of the thousands of citizens residing within their municipalities. Energy conservation is an on-going, everyday affair, and the municipality is directly involved.

The **Transportation Energy Analysis Manual** will consist of chapters on the subject areas listed below. The Manual is being produced chapter by chapter as each is completed. These in turn will be updated as considered necessary.

Executive Summary
1. Program Overview
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Energy Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Program Management
10. Energy Analysis Methods

This chapter, **Street-System Operation**, focuses on and highlights the energy conservation activities which would be applicable for implementation in the operation of street and highway systems.

Additional information on the Manual or on any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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1 Introduction

1.1 General Discussion

The energy used in the transportation sector is predominantly in the form of petroleum, and adds up to almost 50% of all the petroleum used in Ontario. Because of this high energy use, the management of vehicles on the street and highway system is an important energy-conservation activity.

Energy-saving transportation measures, discussed in Chapter 1, can be grouped into four categories. These include strategies to:

- reduce or shorten vehicle-trips;
- improve vehicle consumption characteristics;
- increase load or occupancy of individual vehicles;
- reduce consumption through improved traffic flow.

Improvements in street-system operations are intended as elements of the latter two strategies. An additional three litres of gasoline are used up for every 100 stop/start cycles introduced to uniform travel at 40 km/h. All speed changes consume extra fuel compared to uniform speed. Idling uses up about 0.04 L of gas every minute. If vehicle occupancy can be increased, some vehicles will be removed from the road and a major fuel savings achieved.

Energy is conserved when the transportation function (i.e., people movement) is accomplished more efficiently. The transportation goal of street-system management (which translates into energy savings) is to move the given number of people, at acceptable rates of speed, in fewer vehicles, with enhanced safety. Recognizing that a municipality may be growing and generating some additional travel, the objective is to reduce fuel consumption per person-kilometre of travel.

1.2 Opportunities for Energy Conservation

In general, street-system improvements to promote energy conservation may be divided into two broad groups. The first type seeks to increase the efficiency of the overall system by smoothing traffic flow, decreasing travel time, and increasing roadway capacity. Examples of this type of strategy include one-way street systems and computerized traffic-signal systems.

The second type gives preference to vehicles that carry greater passenger loads, thus enhancing the people-carrying capacity of the system. Examples of this type of improvement include exclusive-use bus lanes, freeway ramps, or metred-ramp bypasses for high-occupancy vehicles (HOVs), and other priority or preferential treatments for HOVs.

Urban pedestrian and bicycle facilities are normally developed to improve access opportunities (e.g., a bikeway) or to enhance amenity (e.g., a pedestrian street). In the past, little attention has been given to these needs. From an energy perspective, such actions will be effective only to the extent that walking and cycling replace automobile trips. Current experience suggests that both sets of action have, so far, been ineffective as a means of saving energy. In some cases they may be counter-productive if the energy costs associated with their construction are taken into account. Nevertheless, consideration of bicycle and pedestrian facilities should be part of an energy-conservation evaluation program so that no opportunity is overlooked.

Street- and parking-system improvements may also include measures that regulate or manage demand. Measures such as automobile-restricted zones that limit access by general auto traffic, variable work-hour programs that lower peak demand, and automobile restraint through pricing, are described in Chapter 5, *Travel Demand Management*.

The measures discussed in this chapter are not new. They have long been used in many places as a means of reducing congestion. Now energy conservation is another factor in traffic-management decisions and justifications.

1.3 Effectiveness of the Proposed Measures

Traffic-flow improvements in particular, and street-system improvements in general, have a high level of general applicability. In situations ranging from a densely developed business district to an expanding suburban area, these types of improvements may be applied with good overall results. Sometimes, however, an extensive application of traffic-flow improvements may be so effective in improving automobile movement that ridesharing, transit usage, or other efforts to encourage use of high-occupancy vehicles could be

adversely affected. Thus, street and traffic improvements must be assessed and implemented within the context of an overall transportation-system management strategy.

A program of complementary measures for street-system improvement and other energy-management strategies should bring out the maximum energy-saving potential of the overall energy-management program. Implementation will require the cooperation of municipal traffic engineers, parking agencies, and transit groups.

Extensively applied, a program of street-system improvement measures could reduce vehicular energy consumption by up to three percent. Such measures will have other benefits as well, in reduced accidents, reduced pollution, personal time savings, and a generally improved urban environment.

1.4 Detailed Description of Measures

The following sections describe many measures that could be applied to enhance the people-moving capacity of the street and highway system. Each section contains the following information:

- strategy and objectives;
- description of measures: advantages and disadvantages;
- effectiveness of measures;
- methods for estimating energy savings;
- implementation experience and considerations;
- application procedures.

2 Traffic-Flow Improvements

2.1 Strategy and Objectives

The aim of traffic-flow improvements is to enable vehicles to achieve a reasonable travel speed, minimize speed changes and reduce the number of stops. Implementation of such measures should enhance vehicle operating efficiency. Vehicles would experience fewer stop-and-go cycles, reduced idling time at intersections, and less congestion — resulting in shorter average-trip travel time, with a corresponding reduction in energy consumption and air-polluting emissions. While traffic-flow improvements enjoy broad general applicability, they might also have a negative impact on potential ridesharing and transit options. For optimum effectiveness, these measures should be considered in the context of transportation system management packages. Some improvements, particularly those of major magnitude, may induce more vehicle-kilometres of travel because of the travel-time benefits that are generated.

The construction of new highways can reduce congestion and inefficiencies on existing facilities, thereby reducing vehicle-hours of travel and energy consumption. On the other hand, such new facilities may permit or encourage new travel and longer trip lengths. A new or substantially widened expressway leading to the centre of a city would affect travel-mode decisions, for example. The overall energy efficiency resulting from these actions will depend on the level of congestion on the facilities being bypassed and relieved, and the amount of new travel that may occur.

Improvements should be implemented through a comprehensive transportation planning process designed to encourage not only enhanced vehicular flow but also the use of transit and other HOVs, and demand-management strategies.

Capacity improvements of 10%-20% are typical of many of the traffic-flow improvements, with a 10%-20% travel-time savings and a 4-6 km/h operating-speed increase. Traffic-flow improvements usually also decrease air and noise pollution, and increase safety.

2.2 Description of Measures

2.2.1 Additional Capacity

As traffic volumes increase and congestion develops, it is desirable to obtain the greatest possible highway capacity from existing facilities in order to maintain efficient vehicle speeds. Additional arterial capacity may be obtained by narrowing shoulders and lanes in order to create additional lanes, or by widening roads to add lanes. Each facility will carry traffic at generally improved speeds and travel-times, thus consuming less energy. (Regarding safety implications, careful evaluation must be made of accident experience to determine that any impact is positive and reduces accidents.) Widening only at intersections, such as by provision of a left-turn lane, will achieve a substantial improvement in capacity and may be satisfactory as a first-phase improvement. Such lanes will increase approach capacity and reduce delay for through traffic.

2.2.2 One-Way Streets

One-way-street systems have gained widespread acceptance throughout North America. They are extensively used in Hamilton, Ottawa, and other cities in Ontario. In general, one-way streets serve to reduce conflict and increase the opportunity for signal coordination and enhanced vehicle capacity. The consequent reduction in stop-and-go travel conditions will reduce energy consumption, although there may be some inconvenience in access due to one-way operation and some additional travel for local circulation. Transit service needs must be carefully considered in establishing systems of one-way streets, in order to maintain good service.

The street system configuration must be suitable for implementation of a one-way system; it must consist of parallel continuous roads of similar character. Business impacts will have to be addressed and local involvement sought to assure support of such changes.

2.2.3 Reversible Lanes/Streets

Closely akin to one-way street systems are reversible lanes. These lanes run in the peak direction of flow, changing during the day to provide maximum capacity in the direction of peak demand.

Reversible lanes and streets achieve a significant increase in traffic-volume carrying capacity and thereby increase average speeds. However, there must be a significant imbalance in peak traffic flow by direction in a corridor to warrant their implementation. Some Hamilton roads which cross the Niagara escarpment offer a good example of this tactic. Proper signing of the lanes is, of course, an essential requirement of such treatment. Again, inconvenience of access, additional travel, and parking restrictions must be considered.

2.2.4 On-Street Parking Restrictions

All-day, daytime, or peak-period parking restrictions can improve car and transit flow, and are generally consistent with energy-conservation goals. The restriction of parking along arterials, usually during peak periods, in the peak direction of travel, yields energy benefits by increasing vehicular speed, reducing stop-and-go travel, and eliminating unnecessary delays and idling. Such programs are relatively inexpensive to initiate and maintain, with costs consisting of signing and enforcement expenses. However, if adequate parking is not available nearby, the parking restrictions may create significant inconvenience and have a negative impact on a business community.

2.2.5 Traffic-Signal Timing Plans

Optimizing traffic-signal timing and coordination can provide substantial energy savings and benefits for vehicular flow. The benefits are achieved through the smoother flow of traffic, reduction in travel time, and reduction in number of stops. Coordination should be considered for any signals within a kilometre of each other, although systems usually involve closer spacing.

Proper signal timing that matches green-time allocation with vehicular demand will reduce unnecessary delay. Special signal phases may be necessary to accomodate heavy turn-traffic at individual locations. In general, however, complex multi-phase signal controls should be avoided; simple two-phase operations are preferable. Selection of proper cycle length as appropriate during the day for differing traffic conditions will maximize capacity and minimize delay. Cycle length should be as short as possible, subject to the following criteria:

- intersection traffic-capacity requirements;
- signal-coordination needs;
- pedestrian crossing-time requirements.

Ottawa, Toronto, and Hamilton have extensive signal systems in which signals on specific streets or in an entire area are coordinated. Opportunities for similar system coordination exist in all cities and towns; many municipalities have implemented their own. Existing timing plans should be updated annually to maximize traffic-flow benefits.

2.2.6 Turn-Conflict Treatments

Delay and congestion are often caused by conflicting vehicle paths which result in other traffic being held up behind the vehicle waiting to make a turn. Left turns are the usual cause of the conflict, but right-turn conflicts with pedestrians can also cause delay. Addition of a left- or right-turn storage lane can maintain smooth through-traffic flow and reduce energy consumption.

Other measures that reduce vehicle-to-vehicle left-turn conflicts are also available and result in enhanced energy conservation. Such actions include installation of two-way centre left-turn lanes, raised median dividers, channelized median openings, and regulatory prohibition of left turns. These treatments show very favourable accident-reduction cost/benefit ratios as well, especially with higher traffic volumes. Prohibition of left turns all day or during peak hours will improve street and intersection operation and reduce delay, but some additional travel may be generated. Where buses turn left, they may be permitted to do so while other traffic is prohibited. This exception will ensure that a time disadvantage is not introduced for buses, and thus the encouragement of high-occupancy-vehicle programs is not jeopardized.

2.2.7 Removal of Unnecessary Devices

In general, improvements in traffic control usually involve the installation of new traffic-control devices. However, elimination of unnecessary STOP signs, four-way stops, and traffic signals will reduce travel times and, therefore, energy consumption. Placing traffic signals on flash operation during periods of low volume provides similar benefits. Intersection control is still necessary for safety and efficient operation, but the form of control can sometimes be changed to reduce the number of vehicle stops and to reduce vehicle idling time at the intersection.

The sequence of intersection control in terms of energy consumption, from low to high, is: no control, YIELD signs, two-way stop, traffic signal, four-way stop.

2.2.8 Freeway Traffic Management

Freeway management considers the operational needs of the total network of facilities, including arterial streets parallel to the freeway. It concentrates on developing actions that make best use of the existing system by maintaining a smooth flow of traffic, with a minimum of capital-intensive system additions. The energy savings result from the reduction in hours of travel through the minimizing of congestion, and the reduction in kilometres of travel through the minimizing of circuitous-route selection.

Freeway-management measures incude:

- early detection of accidents, disabled vehicles, and other incidents that affect the flow of traffic, and early response to such incidents to minimize the length of time that traffic flow is disrupted;
- control of traffic flow at certain points to prevent congestion at more crucial points and to help traffic move through the critical bottlenecks (e.g., through ramp metering or closures);
- priority treatment for higher-occupancy vehicles (such as buses and carpools), to increase the person-moving capacity of the freeways;
- provision of real-time information to motorists, to aid in the efficient utilization of the freeway system by routing them around problem locations.

2.2.9 Bus Bays

When buses stop on the travel-way of a street they can disrupt the flow of traffic, especially during peak periods. This increases vehicle delay, energy consumption, and vehicle emissions. The weaving, added stopping, and restricted sight distances can also be an indirect cause of accidents. Bus bays remove transit vehicles from the travel right-of-way while passengers are loading and unloading, thus improving traffic flow. The disadvantage is that buses may encounter some delay in returning to the traffic stream.

Bus bays are an appropriate measure for all urban areas with public transit service where bus stops cause serious disruptions to traffic and where there is sufficient right-of-way to accommodate a bus bay. Normal bus bay dimensions are 3 m by 30-45 m (10 ft by 100-150 ft).

2.2.10 Improved Signing

Legible and visible signs will eliminate unnecessary travel caused by motorists missing a destination or losing their way as a result of poor information. Street-name signs and guide signs kept in good repair will reduce vehicle-kilometres of travel, while enhancing safety. Large lettering, reflective paint for night visibility, standardized location, and unobstructed view are the key items in providing good information.

2.3 Effectiveness of Measures

Table 2.1 lists the traffic-flow improvement measures that are recommended based on energy savings and other considerations (such as ease of implementation, engineering judgement, and costs). Except for freeway management, all of the measures are low to medium cost. The table shows the potential local impact of each measure in terms of its energy savings. The effectiveness of some of the specific measures in conserving energy is outlined in several other charts which follow.

Optimum fuel efficiency is achieved at a uniform vehicle speed of 50-70 km/h. Stops and delays at an intersection mean increased fuel consumption; improved speeds are the objective of traffic-flow improvement programs. Table 2.2 lists the estimated energy savings that can result from improved speeds on arterial streets. The improvements usually come from improved signal coordination that reduces stops, and from added capacity that permits higher overall speed along the street.

Table 2.1

Potential Energy Saving of Traffic Flow Measures

Measure	Energy impact (% decrease in consumption)	Cost
Coordination of traffic signals	5 – 20	Medium to high
Widening of intersection	20	Low to medium
One-way street systems	5 – 25	Low to medium
Replacement of signs and signals	Decrease varies	Low
Improved signal timing	6	Low
Flashing of signals	Decrease varies	Low
Freeway control	8 – 10	High
Improved street signing	Small decrease	Low
Improved route identification	Small decrease	Low
Turning movement restrictions	4	Low to medium
Reversible lanes	8 – 10	Low
Bus bays	4	Low to medium

SOURCE: *Traffic Management Measures to Reduce Energy Consumption.* Prepared by IBI for the Ministry of Transportation and Communications; May 1981.

Note: The impact measured is on traffic directly affected by the improvement.

Table 2.2

Estimated Gasoline Saving from Arterial Signal System Improvements

Initial speed (km/h)	Fuel consumption (L/100 km)	Fuel saved (L/100 km) due to increase to overall speed (km/h of: 20	25	30	35*
15	21.9	5.4	7.9	9.2	7.9
20	16.5	0	2.5	3.8	2.5
25	14.0		0	1.3	0
30	12.7			0	−1.3

SOURCE: *Traffic Management Measures to Reduce Energy Consumption.* Prepared by IBI for the Ministry of Transportation and Communications; May 1981.

*Fuel consumption at 35 km/h overall speed is 17.0 L/100 km, an increase over that at 30 km/h. therefore 30 km/h overall speed represents optimum speed with respect to fuel consumption.

Each time a vehicle stops from an average speed of 50 km/h (30 mph) and accelerates back to 50 km/h, it costs approximately one-and-a-half cents at current gasoline prices of 40¢/L. Tables 2.3 and 2.4 quantify the amount of energy which is lost as a result of specific types of traffic-control devices that require vehicle stops but could be replaced with less stringent control. Moving from STOP signs to YIELD control, for example, saves approximately 10%, while moving from YIELD control to no sign at all saves another 15%. While these figures cannot be used as sole justification for removing traffic-control devices, they do highlight the need to evaluate carefully all proposed placements and existing signs, with the intent of removing those which are proven to be unnecessary for safety or traffic-control reasons.

The energy savings (expressed in litres per hour) resulting from removal of signals and STOP signs are shown in Figure 2.1. In employing the nomograph, care should be taken to note that hourly volumes vary and so will savings.

Table 2.3

Gasoline Consumed at a Yield Sign Versus a Stop Sign

Average daily traffic (vehicles/day)	Gasoline consumed (L/year) Stop sign*	Yield sign†
1	13.4	8.6
100	1 340.0	858.0
300	4 019.0	2 573.0
500	6 698.0	4 289.0
800	10 716.0	6 862.0
1000	13 396.0	8 578.0
1500	20 093.0	12 866.0
2000	26 791.0	17 155.0
3000	40 187.0	25 733.0
5000	66 978.0	42 888.0

SOURCE: Municipal Transportation Energy Seminar. Ontario; 1980.

* Assumes stop/go cycle decelerating from 50 km/h to a full stop then, without delay, accelerating back to 50 km/h.

† Assumes speed reduction of 32 km/h decelerating from 50 km/h to 18 km/h then accelerating back to 50 km/h.

Table 2.4

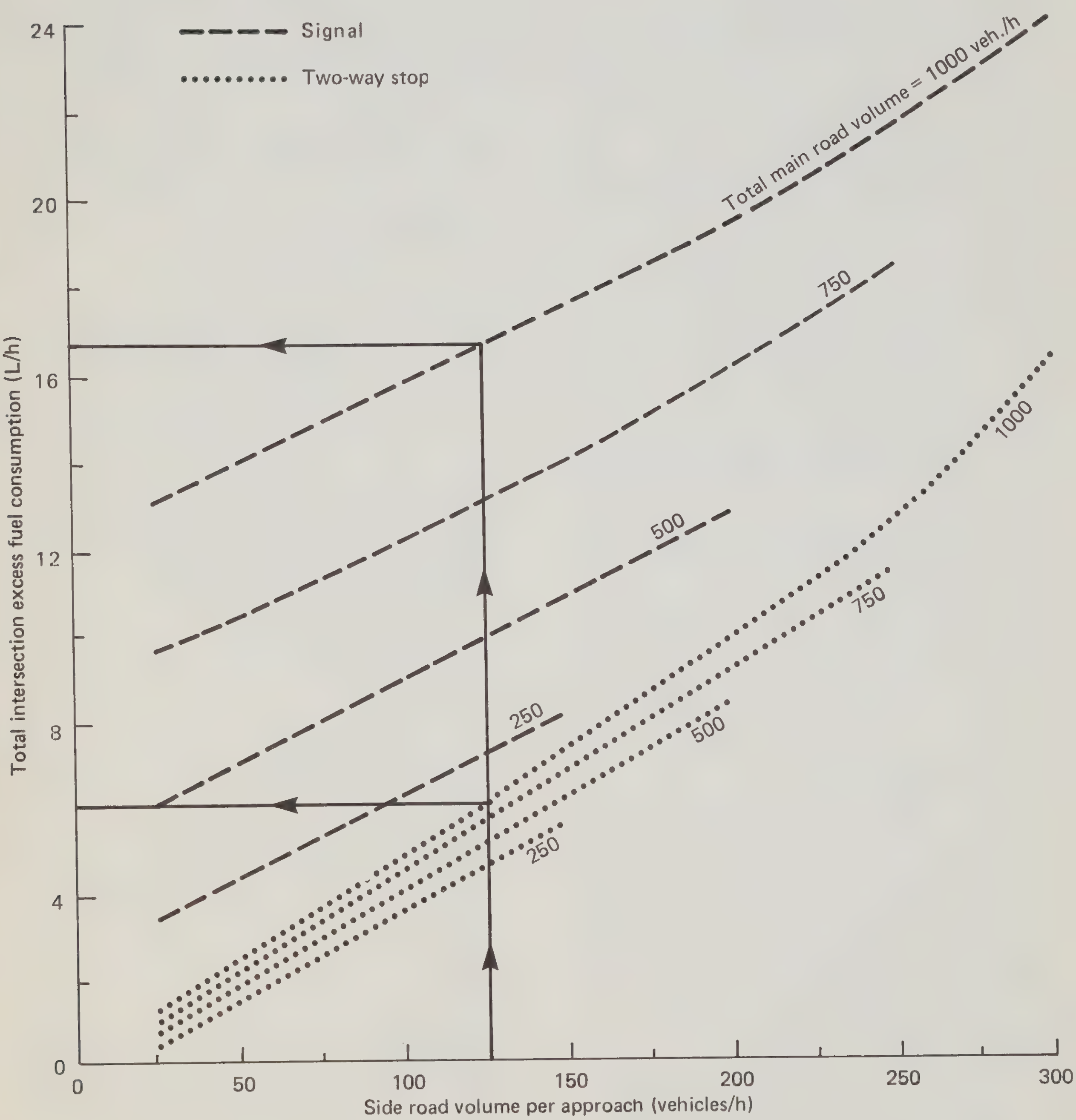
Energy Saving by Modification of 4-Way Stops

Intersection control	Energy consumed* (L/day) Major collector, 3000 veh./day volume	Minor feeder, 300 veh./day volume	Total	Saving (L/year)
4-way stop	110.1	11.0	121.1	—
Stop sign on minor street only	0	11.0	11.0	40 185
Yield sign on minor street only	0	7.1	7.1	41 610

SOURCE: Municipal Transportation Energy Seminar. Ontario; 1980.

* Assumes excess gasoline consumption is 0.0367 L/stop and 0.0236 L/yield for one vehicle.

Figure 2.1
Energy Impact of Signal Removal



SOURCE: Institute of Transportation Engineers.

2.4 Summary of Measures

Descriptions/Typical Applications

- *adding lanes (narrow shoulders/lane)*
- *one-way streets*
- *reversible lanes/streets*
- *on-street parking restrictions*
- *traffic-signal timing optimization*
- *medians and left-turn storage lanes*
- *removing unnecessary control devices*
- *freeway traffic management*
- *bus bays*
- *good informational signing*

Conditions of Applicability

- *Applicable in urban conditions with generally medium to high development density, and access points to major generators*
- *Physical conditions must permit the street or streets to accommodate the strategy*
- *Strategies aimed at improving traffic flow will reinforce the status quo of modal split*
- *When narrowing lanes and shoulders to achieve additional capacity, consider possible adverse safety impacts related to speeds and number of trucks*
- *Transitions into and out of one-way street systems and reversible lanes/streets are key issues in implementation*
- *Constant attention must be given to the operation of signal systems even after they are interconnected or computerized*
- *Removal of unnecessary traffic control devices may encounter public/political resistance, safety, and legal liability issues*
- *Adjacent land-use and land access requirements are key considerations in certain strategies such as on-street parking controls, turn prohibitions, and one-way streets*

Estimate of Effectiveness

- *Gains in street capacity can be substantial, with increases of 10%–20% common*
- *Travel-time savings or speed increases may range from 10%–20%*
- *Low-cost traffic-flow improvements do not generally increase traffic volumes because savings on a per-trip basis are small*
- *An extensive effort may encourage short-term energy savings of up to 3% region-wide*

Energy Evaluation Formula

$$\text{Daily fuel consumption (in litres)} = \frac{[100.4D + 0.63T]\,N}{1000}$$

Where D = *travel distance in kilometres*
T = *travel time in seconds*
N = *number of vehicles per day*

2.5 Evaluation of Energy Consumption

The heart of the process for selecting energy-conservation measures for implementation is the quantification of impacts. Based on the selected improvement, a four-step approach is recommended for calculation of energy savings.

Step 1: Define affected population and type of impact.
Step 2: Choose the evaluation equation.
Step 3: Estimate current and future input variables.
Step 4: Calculate changes in energy consumption.

The basic evaluation relationship can be expressed as:

$$\Delta E = C_1 - C_2$$

Where: ΔE = *change in energy consumption*
C_1 = *energy characteristic* ***before*** *strategy implementation (current)*
C_2 = *energy characteristic* ***after*** *strategy implementation (predicted)*

When considering negative impacts where energy use is increased, the relationship would still apply. Of course, the change in energy would be an increase rather than a decrease.

Some recommendations for carrying out an energy evaluation follow.

- Define a principal impact population as the focus for evaluation.
- Consider secondary impacts only when they are likely to change project decision-making.
- Use a small number of measures of effectiveness or impact.
- Use specific time, distance, and ridership values for analytic calculation if possible.
- Use either transferable parameters from similar areas or detailed estimation techniques to obtain the numerical values for the 'after' condition.

Step 1:

An evaluation of a measure's effectiveness should take into account the specific groups that experience benefits. If there is reason to suspect that others might experience significant negative effects, they must also be considered.

For traffic-flow improvement measures, the analysis group will normally be the traffic on the street where the measures are implemented. Traffic on parallel streets or farther away may be very slightly affected, but these effects can usually be ignored.

Step 2:

The evaluation algorithms used for traffic-flow measures relate to:

- average running time and typical vehicle consumption rate at various speeds;
- frequency of slow-downs and full stops, and consumption due to speed change;
- delay-time and consumption due to idling.

The following equations can be used for most situations related to the measures discussed in the Manual.

A) *Daily fuel consumption (in litres)* $= \dfrac{[100.4D + 0.63T] \times N}{1000}$

Where: D = *distance travelled (km)*
T = *travel time (s)*
N = *number of vehicles per day*

This is a simplified equation that makes assumptions about stops, delays, speed-cycle changes, and average fuel consumption. It is useful where average speeds not exceeding 60 km/h can be measured but other data are difficult to gather.

B) Figure 2.2 presents data that can be used to evaluate energy-consumption variations that are due to speed changes. This would be used if a detailed analysis of traffic characteristics is available and detailed energy-consumption calculations are required.

C) Idling consumption rate = 2.5 L/veh-h — this is an average rate representing the composite fleet of vehicles on the street.

Step 3:

Estimates of the parameters have to be made for the 'before' conditions and the 'after' conditions. The former can be measured in the field, but the latter will have to be estimated from similar experience or by the use of simulation models. The parameters will include distance, speed, stops, and volumes.

Step 4:

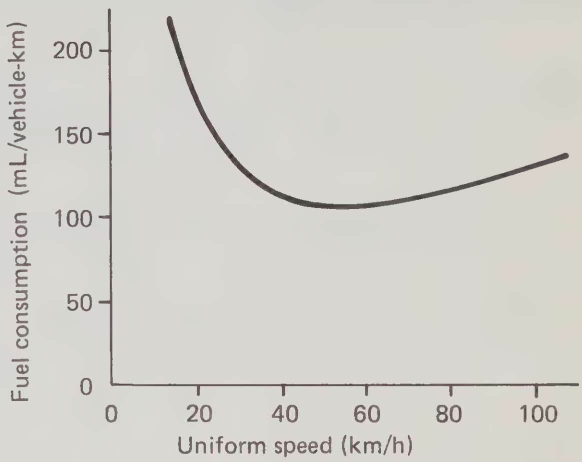
The calculations are performed and the energy savings quantified. Based on this estimate, the measure is evaluated in terms of energy saved. Implementation cost and other considerations such as safety, convenience, and public opinion must also be considered.

Table 2.5 illustrates an energy-consumption calculation for a total street system, Table 2.6 the energy savings for a measure which improves travel speeds on a street in a network.

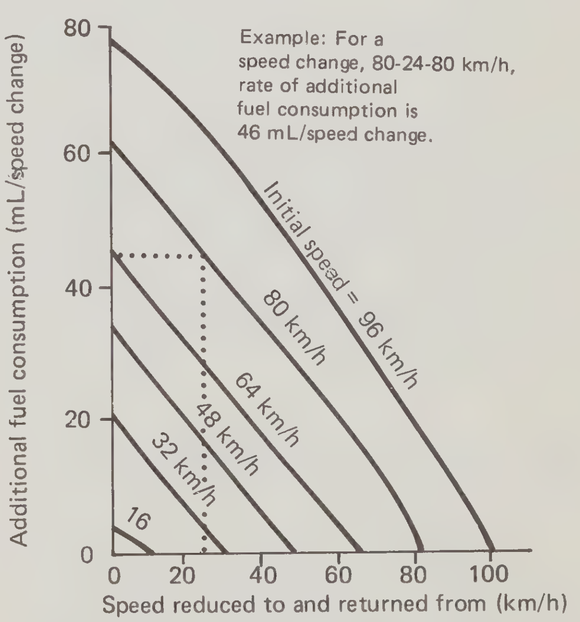
Figure 2.2

Fuel Consumption Estimating Procedure

Fuel consumption from driving at various uniform speeds (for light-duty vehicles)



Additional fuel consumption due to vehicular speed changes above consumption in continuing at uniform speed (for light - duty vehicles)



Idling fuel consumption rate = 2500 mL/vehicle-h

SOURCE: *Procedure for Estimating Highway User Costs, Fuel Consumption, and Air Pollution.* Washington, D.C.: U.S. DOT, Federal Highway Administration; 1980.

Note: Units have been converted from U.S. gallons to litres, and from miles per hour to kilometres per hour. Fuel consumption characteristics are based on a 1730-kg vehicle.

Table 2.5

Simplified Procedure to Estimate Approximate Energy Consumption in Urban Areas

$$\textit{Daily fuel consumption* (in litres)} = \frac{[100.4(D) + 0.63(T)] \times (N)}{1000}$$

where D = total travel distance in kilometres, T = system travel time per vehicle in seconds†, N = number of vehicles. Total city fuel consumption is calculated by summing fuel consumed over all city streets as illustrated below.

Arterial streets

A. 40 km with an AADT‡ of 24 000 and an average operating speed of 50 km/h (total travel time 2880 s)

$$\text{Fuel consumption (per day)} = \frac{[100.4(40) + 0.63(2880)] \times (24\ 000)}{1000} = 139\ 930\text{L}$$

B. 80 km with an AADT of 20 000 and an average operating speed of 40 km/h (total travel time 7200 s)

$$\text{Fuel consumption (per day)} = \frac{[100.4(80) + 0.63(7200)] \times (20\ 000)}{1000} = 251\ 360\text{ L}$$

C. 40 km with an AADT of 15 000 and an average operating speed of 30 km/h (total travel time 4799 s)

$$\text{Fuel consumption (per day)} = \frac{[100.4(40) + 0.63(4799)] \times (15\ 000)}{1000} = 105\ 590\text{ L}$$

Collector streets

80 km with an AADT of 10 000 and an average operating speed of 25 km/h (total travel time 11 520 s)

$$\text{Fuel consumption (per day)} = \frac{[100.4(80) + 0.63(11\ 520)] \times (10\ 000)}{1000} = 152\ 896\text{ L}$$

Local streets

200 km with an AADT of 1800 and an average operating speed of 25 km/h (total travel time 14 400 s)

$$\text{Fuel consumption (per day)} = \frac{[100.4(200) + 0.63(14\ 400)] \times (1800)}{1000} = 52\ 473\text{ L}$$

Total daily fuel consumption = 702 249 L

SOURCE: *Analytical Procedures for Estimating Changes in Travel Demand and Fuel Consumption.* In, Urban Transportation Energy Conservation, Volume II, prepared for U.S. DOE; October 1979.

*Not applicable to average speeds over 60 km/h. The equation is based on a weighted composite of vehicles (1976) by weight class.

†Travel time is the value calculated by dividing system travel distance by average speed.

‡AADT, average annual daily traffic (number of vehicles).

2.6 Implementation Experience

Many towns and cities have implemented the traffic-flow improvement measures that have been described. In the past, their justification has been based on safety, level of service, and convenience. Energy savings are now another significant reason to consider implementation. Results of projects that have been implemented have been recorded and are presented in the tables that follow.

The 11 cities cited in Table 2.7 implemented traffic-signal optimization plans. Average increases of 10% in travel speed were obtained or anticipated. The Toronto results are based on field measurements and indicate increases of 2%-5%. The other estimates are based on simulation models and are therefore speculative.

2.7 Application of Measures

The following procedure should be used by every municipality in their selection of street-system improvement measures.

- Review street system for opportunities to implement traffic-flow improvement measures by locating areas with congestion or travel delays.
- Identify specific problems and select the improvement measures that will improve traffic flow.
- Develop the proposal in functional terms and estimate the change in average speeds, frequency of stops, and speed changes as required for the energy-evaluation equation.
- Calculate energy savings, and consider all other impacts such as cost, access to property, convenience, and publicity requirements.

Table 2.6

Estimate of Fuel Consumption Changes with Signal Coordination

$$\textit{Daily fuel consumption* (in litres)} = \frac{[100.4(D) + 0.63(T)] \times (N)}{1000}$$

where D = total distance travelled in kilometres, T = system travel time in seconds†, N = number of vehicles per day.

Example

Arterial 5 km in length with 4 lanes, no parking, 15 intersections
Carries 24 000 vehicles/day
Average travel time prior to improvements = 560 s (32 km/h)
Assumed improvement in travel time = 15%
Resulting travel time = 476 s (36.8 km/h)

Base condition

$$\text{Fuel consumption} = \frac{[100.4(5) + 0.63(476)] \times (24\,000)}{1000}$$

= 20 515 L/day

After condition (interconnected signals with optimized timings)

$$\text{Fuel consumption} = \frac{[100.4(5) + 0.63(476)] \times (24\,000)}{1000}$$

= 19 245 L/day

Reduction in fuel consumption = 1270 L/day or 6.1% along the arterial

SOURCE: *Analytical Procedures for Estimating Changes in Travel Demand and Fuel Consumption*. In, Urban Transportation Energy Conservation, Volume II, prepared for U.S. DOE; October 1979.

*Not applicable for speeds greater than 60 km/h.

†Travel time is the value calculated by dividing system travel distance by average speed.

- Prepare recommendations and implementation program if energy saving is significant.
- Implement the measure and monitor its impact to compare with estimate.

2.8 Other Information Sources

The Government of Ontario has prepared a more detailed manual, which is available at no cost, to assist municipalities with the implementation procedures. This document is entitled **Traffic Management Measures to Reduce Energy Consumption**. The individual measures noted here are described and presented in more detail in this document.

Another useful reference is a book prepared for the Institute of Transportation Engineers, entitled, **Energy Impacts of Urban Transportation Improvements**.

Table 2.7

Impact of Optimizing Traffic Signal Timing

Location	No. of inter-sections	Study method	Time of day	Average speed (km/h)		
				Before	After	% change
Toronto						
Central area	68	Field measurement	7–9 a.m.	25.4	26.5	+ 4.4
			10–12 a.m.	27.5	28.1	+ 2.3
			1–3 p.m.	24.9	26.2	+ 5.2
			4–6 p.m.	22.0	22.0	0
Suburban area	51	Field measurement	7–9 a.m.	34.3	33.8	− 1.4
			10–12 a.m.	45.4	46.8	+ 3.2
			1–3 p.m.	44.2	45.2	+ 2.2
			4–6 p.m.	34.9	33.6	− 3.7
San Jose, CBD	46	TRANS simulation	4–6 p.m.	24.8	25.3	+ 1.9
Los Angeles, inner city						
Broadway – Figueroa	26	TRANS simulation	3–4 and 5:30–6 p.m.	28.0	33.1	+21.1
			4–5:30 p.m.	24.8	30.4	+22.7
Pico Boulevard	6	TRANS simulation	2:30–3:30 p.m.	33.9	40.1	+18.0
			4:30–5:30 p.m.	32.5	34.6	+ 6.4
Wilshire Boulevard	45	TRANSYT simulation	a.m. peak	21.1	23.2	+ 9.9
Macon GA, CBD	54	SIGOP simulation	7:45–8:45 a.m.	20.4	23.2	+13.4
			4:45–5:45 p.m.	18.8	22.0	+17.1
Inglewood CA, citywide	60	SIGOP simulation	7–10 a.m.	36.8	49.7	+35.0
			3–6 p.m.	35.4	48.3	+36.0
Montgomery AL, CBD	50	TRANSYT simulation	a.m. peak	26.2	32.6	+24.0
			Off peak	30.7	32.6	+ 6.0
			p.m. peak	28.9	32.0	+11.0
Charlotte NC, CBD fringe	10	TRANS simulation	5–6 p.m.	12.4	13.9	+12.0
Washington DC, CBD	40	UTCS-1 (NETSIM)	Off peak	19.3	21.3	+10.4
Average						
All locations						+11.8
Toronto and San Jose						+ 1.6
Others						+18.4

SOURCE: Wagner, T.A. *Urban Transportation City Conservation Analysis of Traffic Engineering Associations.* Prepared under subcontract to Cambridge Systematics, Inc. for the U.S. Department of Energy; September 1973.

Note: Toronto and San Jose were aggressively managed, computerized signal systems in the 'Before' case.

3 Preferential Treatment for High-Occupancy Vehicles

3.1 Strategy and Objectives

High-occupancy vehicles (HOVs) are vehicles which carry more than one person. A transit vehicle carrying many passengers is the most common form of HOV; a vanpool is an increasingly common form; carpools can be considered HOVs for some applications.

Preferential treatment for high-occupancy vehicles is a direct attempt to give priority to movement of multiple-occupant vehicles in preference to single-occupant ones. These tactics all create dedicated road space which serves to reduce travel time for HOVs and to improve the service level of transit in particular. Such improvements enhance the people-moving productivity and energy efficiency of the street system.

Preferential treatments have two general requirements. The first is that adequate road space must exist to prevent a disproportionately detrimental effect on general highway traffic. The second is that, to be effective, HOVs must provide significant travel time savings over other street traffic. This latter requirement dictates that priority treatments are generally successful only in the peak travel-time period.

HOV strategies have a number of interrelated objectives. They strive to induce commuters to shift to higher-occupancy travel modes, and thereby remove some vehicles from the road and reduce overall vehicle-kilometres of travel. They are also designed to minimize total person-delay in the transportation system. The increased efficiency of the transportation service is measured not only by improved vehicular flow of those vehicles remaining on the facility but also by the increase in the number of persons who are served during the peak period even if energy consumption changes only minimally. By making better use of available system capacity, other objectives, such as reduced transportation construction costs and reduced air-polluting emissions, are also achieved.

An excellent example of providing preferential treatment for HOVs is found in Ottawa on the Ottawa River Parkway. Opened in March, 1974, this 3-km busway provides peak-period HOV service (6:30 to 9:30 a.m. and 3:30 to 6:30 p.m.) by restricting the two off-peak direction lanes for exclusive use by buses running in both directions. The busways were implemented at a cost of $425 000. Mean bus travel time was reduced 25%, and the routes using the busway experienced an average ridership increase of 60%.

3.2 Description of Measures

3.2.1 HOV Lanes

Exclusive HOV lanes increase the attractiveness of bus, vanpool, and carpool use by reducing travel time. These lanes can be implemented on expressways and major arterials. They may be coordinated with preferential signal systems, expressway ramp metering, and non-HOV turning restrictions which save more time and complement the basic objective of giving HOVs a time benefit. The shift in travel mode reduces both auto travel and congestion, with further resultant savings in energy consumption.

There are two general treatments of HOV lanes. These are:

- *take-a-lane*, in which an existing travel lane is used as the HOV lane;
- *add-a-lane*, in which a new lane is added to the facility.

These two treatments may have substantially different impacts on travel. In the *take-a-lane* alternative, if sufficient traffic is not diverted to the HOV lane, the resultant congestion in the remaining lanes may increase energy consumption more than the HOV lane reduces it. The *add-a-lane* treatment does not have this problem, but of course it is more expensive and can only be implemented where physical conditions allow.

The cost of implementing HOV measures on existing roadways depends upon the length of the treatment, the availability of a continuous travelway for transition to and from the lanes, the level of enforcement required, and the signing and pavement marking needed. The effectiveness of the measure should not be measured only at the outset. Mode-of-travel changes require time. Six months or a year after implementation, there would probably still be diversion and travel changes.

The addition of an exclusive HOV lane within existing highway rights-of-way adds capacity to congested corridors, dramatically improving travel

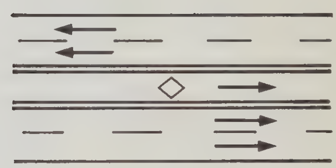
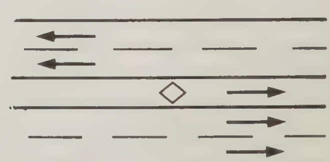
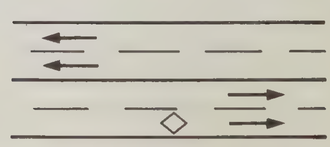
time for HOVs and marginally improving travel time for other vehicles as well. This action requires relatively high capital investments if an exclusive roadway is built (such as on the Shirley Highway in Washington, D.C.). Adding a lane adjacent to existing lanes can also be very costly, although on several existing projects the cost was kept down by compromising on design standards for lane and shoulder width.

The general possibilities for HOV preferential lanes, along with a description and example of each, are shown in Table 2.8.

HOV lanes can be designated for carpools, vanpools, and/or transit vehicles. A rule related to the number of occupants required to constitute a carpool is necessary on treatments where carpools are permitted. HOV-lane treatments are generally designed to operate in both the a.m. and p.m. peak directions through reversing direction or changing sides of the roadway. However, in some situations, they may operate only in one peak; in others, they may operate all day.

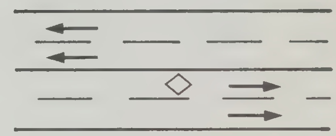
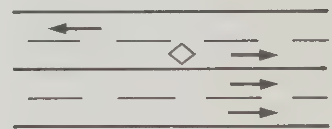
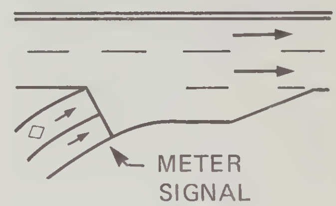
Table 2.8

HOV Treatment Descriptions

Treatment	Description	Example*
Exclusive HOV roadway	A roadway on its own right-of-way for HOVs only	
Controlled access roadway		
Separated lane	Lanes for HOVs permanently separated from other lanes and within the right-of-way of a freeway (generally 2 lanes are provided)	
Concurrent-flow lane	An HOV lane on a freeway, not permanently separated, in which HOVs travel in the same direction to traffic in the adjacent lane	
Contra-flow lane	An HOV lane on a freeway, not permanently separated, in which HOVs travel in the opposite direction to traffic in the adjacent lane	
Arterial roadway		
Separated lane	HOV lanes permanently separated from other lanes and within the right-of-way of the arterial (generally two lanes)	
Concurrent-flow curb lane	The right curb lane on an arterial, not permanently separated, in which HOVs travel in the same direction as traffic in the adjacent lane	

* HOV lane indicated by diamond.

Table 2.8 (continued)

Treatment	Description	Example*
Concurrent-flow median lane	The lane to the right of centre of a two-way arterial, not permanently separated, in which HOVs travel in the same direction as traffic in the next lane to the right	
Contra-flow lane	The lane to the right of a two-way arterial, not permanently separated, in which HOVs travel in the same direction as traffic in the lane(s) to the left of centre. Also a lane on a one-way arterial in which HOVs travel in the opposite direction to other traffic	
Bottleneck		
Metered ramp bypass	A free-flow lane for HOVs on a ramp to a freeway, adjacent to a lane with metering signals	
Exclusive ramp	A ramp between two roadways for the exclusive use of HOVs	
Queue jump	A lane for the exclusive use of HOVs at a signalized intersection, a freeway to freeway ramp, or other bottleneck where traffic backs up	

* HOV lane indicated by diamond.

Enforcement is an extremely important feature of HOV-treatment projects. A high violation rate would eliminate much of the advantage of the HOV lane and therefore preclude the achievement of the modal shift benefits.

3.2.2 Traffic-Signal Controls

Bus and high-occupancy-vehicle priorities may also be established through traffic-signal control. Signal priority treatments that reduce HOV-vehicle- and person-delay at signalized intersections include:

- traffic-signal timing-plan optimization to favour buses;
- pre-emption of traffic signals by buses;
- special bus phases or exemption from turn prohibitions.

Traffic-signal timing coordination and pre-emption should be designed to reduce total person-delay by giving transit vehicles priority over other vehi-

cles. Timing programs can be made to favour phases that are used by buses. For signal pre-emption, units which communicate directly with the traffic controller are installed on the transit vehicles. These alter green phases to allow the bus to clear the intersection. Finally, special signal phases, activated by the bus approaching the intersection, can be introduced for left-turning buses or to add a separate phase for buses in the curb lane. A simple form of special treatment is to allow buses to make a left turn where other traffic is prohibited from doing so.

Signal-timing adjustments to favour transit should not be too disruptive to any established signal coordination. If the additional green time for buses occurs immediately before or immediately after the normal green phase, signal-system progression can be maintained reasonably well for other traffic.

Energy impacts of signal pre-emption should be carefully analyzed, since reducing person-delay or giving transit vehicles priority may not reduce overall fuel consumption if too much disruption to other traffic flow is introduced.

Freeway ramp metering with bypass lanes for buses or carpools is another related type of signal priority. HOVs can go to the front of the signal queue by using a bypass lane.

In general, costs involved in implementing traffic-signal modifications are reasonably low. A bus pre-emption system may cost $500 per bus and $1000 per intersection. A special bus signal phase may cost $5000 per intersection.

3.2.3 Preferential Parking

Parking policy can be used to encourage the use of HOVs; parking actions are usually directly related to a carpool or vanpool program (see Chapter 4, *Ridesharing*, for further discussion of these measures). Some actions which provide preferential treatment for HOVs are:

- *Restriction of Parking Supply*. This limits the availability of parking spaces and forces increased use of transit or higher vehicle occupancy. Such action is applicable where the attraction of trips is not an issue, such as downtown in a major city.
- *Reduced Parking Cost*. This action provides preferential parking rates for carpools with a given number of riders. With a cost incentive added to other benefits, this should encourage higher car occupancy.
- *Park-and-Ride Lots*. Provision of parking lots conveniently located near transit service will encourage the use of transit. This will normally be part of a transit program (see Chapter 3 for further discussion of energy conservation measures for transit systems) but it is also a suitable action in any HOV preferential-treatment plan.
- *Preferred Parking-Space Location*. This action can take the form of the convenient location of an entire lot, or that of reserving some conveniently located spaces in a regular lot for use by car- and vanpools. This can reduce walking distance and provide more rapid exit to the street system, compared to the remaining spaces.

3.3 Effectiveness of Measures

Travel-time savings achieved by HOV lanes will be a function not only of the lane but also of the adjacent highway congestion. The travel-time difference will determine the number of single-occupant auto trips that can be converted to transit ridership or carpools, and thus the energy-savings benefits that will result from the HOV-lane treatment.

Experience from other HOV projects suggests that a total travel-time saving of at least five minutes is necessary before a modal shift is likely to be considered by drivers. However, this saving can be achieved over several HOV treatments rather than within a single action. Therefore a measure's potential benefit should consider the entire trip made by the commuter. Each measure alone may not be effective, but it may be important as part of a series of HOV measures.

Table 2.9

Typical Time Savings for Bus Priority Options on Arterial Streets

Travel time in mixed traffic (min/km)	Time saved (min/km) by: Normal-flow bus lane	Contra-flow median bus lane	Off-street busway
12.4 (4.8 km/h)	3.7	5.0	9.3
9.3 (6.4 km/h)	2.5	3.7	6.2
6.2 (9.6 km/h)	1.6	2.2	3.1
4.7 (12.9 km/h)	1.2	1.2	1.6
3.7 (16.1 km/h)	0.6	0.6	1.6

SOURCE: Estimated from Wilbur Smith and Associates. *Bus Rapid Transit Options in Densely Developed Areas*. 1975.

Even though the difficulty in implementing HOV-priority options on arterial streets is much greater than on freeways, the potential time savings are also much higher. On freeways, bus lanes have reduced travel time by about 0.5 min/km. As noted in Table 2.9, if an arterial street were operating at an average of 6 min/km or 10 km/h, then a normal-flow bus lane could expect to save up to 2 min/km if it operated at an average of 15 km/h.

The energy saving that will result from an HOV treatment is directly related to the modal split and number of vehicles removed from the street system. The changes in modal split depend on time savings achieved by using the transit or carpool HOV measure. Increases in transit ridership are difficult to relate to time savings as separate from other factors. The bus-travel-time improvements will help keep transit service competitive and thus help to keep existing riders on the system, as well as attracting new riders. Carpool formation based on time savings is also difficult to predict because of the many factors that are likely to be involved in an HOV treatment.

3.4 Summary of Measures

Description/Typical Applications

- *exclusive roadway*
- *arterial high-occupancy vehicle facility improvements: concurrent-flow ("take-a-lane" or "add-a-lane"); contra-flow ("take-a-lane")*
- *bus malls/streets*
- *bus-priority signal system*
- *bottleneck-bypass lane*

Conditions of Applicability/Design Criteria

- *Two or more same-direction lanes must be available*
- *Maintenance of adequate delivery and service access to properties is essential*
- *200-300 daily buses (800 passengers) and more than 40 peak-hour buses are essential for a reserved transit lane*
- *Implementation of carpool and vanpool preferential measures is difficult in an arterial setting*
- *Enforcement is a costly but critical link*
- *Good technique to reduce circuitous bus routes because of one-way street or other operational problem*
- *Total travel-time savings should be in excess of 5 min over normal automobile travel to generate modal shift*
- *Multiple improvements should be considered in order to achieve 5-minute requirement*
- *Car pools and van pools should be admitted to HOV facilities only if they do not interfere with transit operations and benefits*

Estimate of Effectiveness

- *Preferential treatments should save from 0.5 to 2 min/km*
- *For a normal range of application, HOV ridership could increase 15%–20% in the applicable corridor*
- *Depending on the base mode share, VKT in the corridor and energy consumption may be reduced 2%–3%, and 1% over a region*
- *Preferential treatments will reduce transit operating cost 1% per bus-kilometre*

Energy Evaluation Formula

Energy saved =

$$\frac{\text{vehicles removed} \times \text{average trip length}}{\text{fuel consumption rate}}$$

3.5 Evaluation of Energy Consumption

The key item that has to be calculated is the number of vehicles that are removed from the system through carpool formation or new transit ridership. Equations for new carpool formation have been developed for a number of cities, but their application in another situation has to be done selectively and with judgement.

One equation for carpool formation is as follows:

$$C_1 = C_O\,(1 + e\,[(t_g - t_s)/t_g])$$

Where:

C_1 = *number of carpools after HOV measures*

C_o = *present number of carpools*

e = *3.0 for 3-or-more carpool-size rule*

= *0.05 to 1.6 for 2-or-more carpool-size rule (use of 1.0 is generally satisfactory for a first estimate)*

t_g = *travel time in general lanes (non-HOV)*

t_s = *travel time in special lane (HOV)*

Transit-ridership gain is difficult to predict based on HOV-lane travel-time benefits. However, if some estimate of increased ridership can be calculated, the number of cars removed from the street system can be used for the calculation of energy savings.

Energy-consumption reductions are then calculated using vehicle- kilometres of travel and fleet consumption rate.

energy savings (L/yr) = vehicles removed from daily street volume × average round trip commuting distance × workdays in a year × fuel consumption rate in L/100 km

Overall effects on energy consumption could also be affected by higher or lower speeds for non-HOV traffic. Fuel consumption changes can be estimated using the equation:

$$f = 10 + 2.35\,t$$

Where: f = *fuel consumption per vehicle in L/100 km*

t = *mean travel-time rate in min/km*

Some sample calculations are shown in Tables 2.10 and 2.11.

Table 2.10

Example of Carpool Formation and Calculation of Energy Saved

Use 2-person carpool rule on a 10-km freeway HOV lane.

Present number of carpools, C_0	1000
Travel time in non-HOV lanes, t_g	15 min
Travel time in HOV lane, t_s	10 min

Using the equation given in section 3.5 to calculate the number of carpools after HOV measures, C_1

$$C_1 = C_0\left(1 + e\left(\frac{t_g - t_s}{t_g}\right)\right)$$

$$C_1 = 1000\left(1 + 1.0\left(\frac{15 - 10}{15}\right)\right)$$

$$= 1000\,(1 + 1.0\,(1/3))$$

$$= 1333$$

or an increase of 333 carpools.

If 333 new carpools were formed, the energy saving calculation would use these factors:

- 333 new carpools assumes that 333 cars have been removed from the traffic (if it is carpools per hour, the number must be adjusted to cover the peak period)
- one-way average work-trip distance is 10 km
- 2 trips are made per day
- there are 250 working days per year
- average auto fuel consumption is 14 L/100 km or 0.14 L/km

Annual energy saving = 333 × 10 × 2 × 250 × 0.14
= 233 100 L/year

Table 2.11

Example of Energy Consumption Calculation for Speed Change in Non-HOV Lanes

Other energy factors to be considered are changes in fuel consumption by non-HOVs due to higher or lower speeds. Fuel consumption in the lower speed ranges (below 100 km/h) can be estimated using the formula

$$f = 0.10 + 0.0235t$$

where f = fuel consumption per vehicle (L/km) and t = mean travel time rate (min/km).

Non-HOV traffic volume	3500
Non-HOV speed before HOV lane	50 km/h
Travel time rate	1.20 min/km
Non-HOV speed after HOV lane	45 km/h
Travel time rate	1.33 min/km
Length of HOV lane	10 km

Fuel consumption per vehicle before HOV lane

f = 0.10 + 0.0235(1.20)
= 0.12820 L/km

Fuel consumption per vehicle after HOV lane

f = 0.10 + 0.0235(1.33)
= 0.13133 L/km

Difference = 0.00313 L/km

Annual increase in non-HOV fuel consumption (assuming 2 trips per day and 250 working days per year)

= 0.00313 × 10 × 2 × 250 × 3500
= 55 000 L/year

3.6 Implementation Experience

While the application of HOV treatments throughout North America has been increasing, application in Canada has been limited. Implementation of ramp-metre bypasses, exclusive CBD bus lanes, and other similar small-scale strategies is still growing. However, the political sensitivity of preferential facilities on high-volume freeways has led to slowed implementation.

Table 2.12 describes four priority bus-lane projects implemented in Canada and summarizes their resultant travel-time savings.

The dual effect of preferential bus and carpool lanes can be seen not only in travel-time savings but also in changes in automobile occupancy. As summarized in Table 2.13, increases in automobile occupancy have been reported as an effect of HOV treatments.

Energy savings on a regional scale can be as high as a one percent reduction in consumption if preferential treatment measures are implemented extensively.

Table 2.12

Examples of With-Flow Priority Bus Lanes on Major Arterials

Location	Project details	Use	Time saved	Comments
Toronto, Ont. Eglinton Ave.	Project length: 1.9 km (a.m. peak) 3.2 km (p.m. peak) Hours of operation: 7:00–9:00 a.m. 4:00–6:00 p.m. With-flow bus priority lane acting as a tributary to the main north-south subway line	60 buses/h (a.m. peak) 51 buses/h (p.m. peak)	8 min/bus per one-way trip	Only buses and emergency vehicles permitted to use the priority lanes Automobile travel time increased 2–5 min along corridor Greater regularity of bus trip times achieved Implementation cost $50 000
Ottawa, Ont. Albert/Slater and Rideau schemes	Started Sept. 1973 Length: 5.5 km Hours of operation: 7:00–9:00 a.m. 4:00–6:00 p.m. Four bus-lane streets are situated in the CBD. They serve as origin/destination of routes entering the CBD in the peak periods	80 buses/h during peaks	0.5 min/bus per trip	Taxis allowed to use the reserved lane for loading and unloading passengers only Vigorous enforcement accompanying the introduction of the experiment resulted in excellent observance of the new regulations Improvement in bus running speeds of 2–35% Automobile flow is unaffected
Edmonton, Alta.	Started 1973 Five with-flow schemes with total length of 2.3 km All operational 24 h/day Each scheme is one of: (a) two lanes on 6-lane divided arterial; (b) one-way on 4-lane arterial; (c) two-way on 4-lane arterial	22–120 buses/h during peaks	Not available	Emergency vehicles permitted to use bus lanes
Montreal, Que.	Started 1975 Three with-flow schemes with total length of 2.6 km	45–75 buses/h during peaks	Not available	Taxis permitted to use bus lanes

SOURCE: M.M. Dillon Ltd. *Non-Capital Intensive Transportation Option.* Prepared for the Winnipeg Tri-level Committee; October 1978.

Table 2.13

Summary of Effectiveness of Various Bus and Carpool Priority Measures

Measure	Time saved (min/km)	Other effects	Cost ($/VKT)
Busway			
vs. freeway	0.8 (0.6–0.9)*	Car occupancy increase of 0.06 persons/car (with car pools)	—
vs. city streets	3.1 (2.1–4.1)		
Contra-flow bus lane			
Bridge or tunnel approach	3.1 (2.0–4)	10% increase in freeway volumes due to removal of buses	—
Other	0.8 (0.4–1.1)		
Normal-flow HOV lane			
Queue bypass	1.9 (1.2–2.4)	Car occupancy increase of 0.09 persons/car	0.81
Other	0.8 (0.4–2.5)		
Special bus ramp	4.7 (3.1–6.2)	Car occupancy increase of 0.10 persons/car	—
Queue bypass (buses and carpools)	3.1	—	—
Metered ramps	1.2 (0.6–1.9)	Up to 29% increase in freeway speed	0.10

*Time saved data are expressed as typical values with the range in parentheses.

Table 2.14

Guidelines for Identifying Potential Locations for HOV Treatment

HOV treatment	General situation	Specific indicator
HOV lanes	Roadway or corridor which is a primary, high-volume commuter route	Volume during peak hour in peak direction on an arterial is 1000 and on a freeway is 3000 vehicles per hour
	Roadway which provides access to a major employment centre	Potential location is indicated
	Location where there is a physical constraint or bottleneck, e.g., bridge, tunnel, interchange, or restricted access	Potential location
	Ramp which is currently metered or may become so	Potential location
	Route which has significant current or potential transit and/or other HOV usage	Any location where an HOV lane would significantly improve transit operations Peak-hour auto occupancy of at least 1.3 persons per car
	Roadway which experiences congestion or where it is anticipated	Arterial overall speed less than 30 km/h or freeway overall speed less than 45 km/h
Traffic signal treatment	Route which has a significant number of current or potential transit vehicles	Peak-hour transit volume of 10 vehicles
	Arterial roadway with an HOV lane	Closely spaced signals (0.5 km) for signal progression
Parking policy	High relative demand for CBD and CBD fringe area parking	Average walk of 400 m or more from parking space to CBD employment locations
	Relatively high price for all-day CBD parking	All-day rate is 80% or more of eight times the hourly rate Monthly parking is over $30
	Substantial inter-urban commuter travel generated	When there is 1.5×10^6 person-km of one-way, a.m. peak-period work travel from one municipality to others, park-and-ride lots or carpool lots may be justified

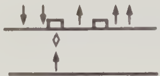
3.7 Application of Measures

There are five steps that should be followed when considering an HOV program. These are summarized as follows.

- Identify locations where the traffic-demand conditions are such that special HOV treatment would encourage HOV use or produce net savings in person-travel time. Congestion is the primary indicator of such conditions. Table 2.14 shows the basic guidelines that can be used to identify potential locations for HOV treatment.
- Identify the best type of treatment for consideration, given existing conditions and likely changes. Physical characteristics will influence feasibility. Table 2.15 shows the options available for HOV lanes.
- Assemble data, establish treatment design, and evaluate energy savings, using equations noted earlier.
- Select HOV measures and prepare detailed design.
- Implement treatment and monitor project impact.

Table 2.15

Index of Theoretically Practical HOV Lane Treatments

Type of treatment	Present facility type*: Controlled access road	Arterial road: One-way	Arterial road: Two-way divided	Arterial road: Two-way undivided	Bottleneck
Concurrent flow					
Right curb lane					No
Inside lane					No
Left curb lane	No		No	No	No
Contra-flow					
Right curb lane	No†	No†	No†	No†	No
Inside lane	 ‡	No†			No
Left curb lane	No†		No†		No
Exclusive facility					
In median	 §	No	 §	No	No
HOV roadway	 §				No
Ramps and queue jumps‖					
Metered ramp bypass	No	No	No	No	
Exclusive ramp		No	No	No	
Queue jump	No	No	No	No	Yes¶

Note: The diamond symbol is recognized in signing and marking as the indication of an HOV lane.

*The diagrams show the minimum number of lanes required on the present roadway if a lane is to be taken for HOVs. If a roadway has fewer than the number of lanes shown, the HOV lane must be added.

†These treatments are physically possible but are not recommended because they involve driving to the left of oncoming traffic.

‡HOVs should be limited to vehicles with trained drivers, i.e., transit and registered vanpools. A contra-flow lane is not possible on a roadway with left-side ramps.

§These treatments require the addition of a lane. Although the remaining treatments are shown as take-a-lane, an add-a-lane treatment on any present facility is a more desirable means of establishing the HOV lane. If, to accommodate growth, additional capacity is to be provided in a corridor, the new lanes could be designed for HOVs.

‖Ramps and queue jumps are short treatments and are related to one specific location. The other treatments apply over longer distances.

¶This treatment can take the form of any of the treatments shown elsewhere in this table plus any HOV intersection approach and turning lanes. It is intended as a short treatment to bypass localized congestion.

3.8 Other Information Sources

The Government of Ontario has prepared guidelines for the identification of HOV opportunities, and the design of the strategy. The report, entitled, **Guidelines for Preferential Treatment for High Occupancy Vehicles**, is available on request.

Information can be obtained from:
TEMP
Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8
(416) 248-7296

4 Bicycle Facilities

4.1 Strategy and Objectives

The bicycle is the most energy-efficient urban transport mode, since a cyclist can pedal more than 35 km on the energy equivalent of 1 L of gasoline. If bicycle ridership for purposes other than recreation can be encouraged, vehicles will be removed from the roadway and energy consumption thus reduced.

4.2 Description of Measures

Energy-related transportation-management actions to encourage bicycle travel include:

- bikeway systems (separated or shared facilities);
- bicycle storage facilities (downtown and at transit stops);
- bikeway maps;
- revised intersection regulations;
- administrative support action.

4.2.1 Bikeway Systems

Many communities in Canada and the United States provide separate or shared facilities for cyclists. System components, as defined for the Ottawa-Carleton Region, are as follows.

Bicycleway or Bikeway:

Any road, street, path, or way which, in some manner, is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.

Bicycle Path or Trail:

A separate trail or path for the exclusive use of bicycles, or for the use of pedestrians and bicycles. Where such a trail or path forms a part of the highway, it is separated from the roadway for motor-vehicle travel by an open space or barrier.

Bicycle Lane:

A portion of a roadway which has been designated for preferential or exclusive use by bicycles. It is designated as a separate portion of the roadway by paint stripe, curb, or other similar device.

Bicycle Route or Shared Roadway:

Roadway which is officially designated and marked as a bicycle route but which is open to motor-vehicle travel and on which no bicycle lane is designated.

4.2.2 Bicycle Storage Facilities

The provision of bicycle lockers, racks, and other storage facilities is an important way to enhance the convenience and security of bicycle trips. Often provided at major activity centres or at transit stations, they give the bicyclist an adequate storage facility and minimize the potential for theft.

4.2.3 Bicycle Maps

Preparation and public distribution of maps (either free or at nominal cost) would help by showing recommended cycling routes on the existing street system. This makes the public more aware of cycling as an alternative, as well as making cycling more attractive by recommending alternative routes to high-volume arterials.

4.2.4 Revised Regulations at Intersections

Regulations designed to give cyclists positive controls or priorities at intersections would help assure continuity of the bike-route network. Special bicycle-actuated signal phases and turn controls are examples. Intersection design may include curb ramps for bicycles, offset pathway crossings, and grade-separated crossings.

4.2.5 Administrative Support

A number of activities that organize and support bicycle use can be made available in a municipality. These include:

- registration of bicycles;
- safety programs;
- user training programs;
- promotional material;
- enforcement of regulations.

The opportunities for installing bicycle facilities vary among parts of an urban area. The width, use, complexity and continuity of the street sys-

tem, the availability of corridors through park land, the presence or absence of grades, the climate and culture, and the likelihood of attracting riders will influence feasibility.

Careful analysis should be undertaken before general traffic lanes are designated for bicycle use only. Not only are there safety issues associated with bicycle use relative to parked and moving cars, but experience in Calgary has shown that resultant traffic congestion may outweigh any positive energy savings resulting from bicycle travel.

Maintenance and enforcement costs as well as capital costs should be considered before implementation. Energy costs of installing bicycle facilities should be balanced against anticipated savings; net benefit is desirable from an energy standpoint.

4.3 Effectiveness of Measures

Potential energy savings depend upon the number and length of auto-driver trips that would be attracted to improved bicycle facilities.

Many studies have quantified the energy savings that can be achieved assuming that the potential modal shift from car to cycle is effected [see References 1, 2, 3]. The U.S. DOT suggests that an increase in bicycle usage of between 50% and 100% would induce a daily reduction in U.S. vehicle-kilometres of travel of between 13.3 and 26.5 Mkm. If this goal is attained, it will result in a gasoline saving of 7.9 to 15 million barrels per year [2].

A study in New York City revealed that the impacts of an auto-to-bicycle mode shift of one percent of total vehicle-kilometres of travel would save 12.7 ML of gasoline on an annual basis [1]. In the Toronto context, this would approximate 4.5 ML annually. While such potentials exist in theory, experience suggests that the changes in mode and the gasoline savings attributable to them are likely to be small. Despite the many social and private benefits gained through bicycling, construction or designation of bikeways in congested urban areas, in itself, may not be enough to cause a significant number of people to switch to bicycle use, or even to assure reasonable use of routes [4].

Moreover, the dollar savings from a modal shift (generally $100 to $300 per year) are really too small to induce such a shift [see References 5, 6, 7]. Other factors limiting widespread shifts to bicycles include the following.

- Weather – for many parts of Ontario, adverse weather conditions, such as ice and snow, make bicycle use virtually impossible for a significant portion of the year.
- General absence of shower facilities at the trip destination.
- General absence of orderly and reasonably theft-proof bicycle storage facilities at the trip destination.
- Residential patterns — the typical one-way bike trip is about 5 km long and few are longer than 8 km. In contrast, the average work trip is substantially longer, except in small Ontario communities.
- Safety, circuity, and recognition of the bike-route special facilities tend to improve the perceived safety of the bicyclist considerably. However, circuity is the major reason cited by bicyclists for not using a facility that would take them out of their way by up to two blocks [7].

The following factors underlie the potential demand for bicycle trips.

- It is not likely that commuting trips by bicycle will ever constitute a significant portion of total commuting trips in Ontario except, perhaps, in very specialized situations.
- Commuting trips to schools appear to offer the greatest potential benefits to bikeway users, in terms of both economy and safety. Such potentials are particularly good in communities with large college-student populations.
- Bicycle shopping trips offer little potential for expansion in most communities and should be considered as an incidental factor in bikeway planning.

These findings suggest that the potential energy savings attributable to bicycle-related actions would be small. Therefore the methodology that follows is general in nature, and can serve as a broad guideline for further analysis of the energy savings attributed to bicycling.

4.4 Evaluation of Energy Consumption

The analysis approach that follows is suggested because the modal shift from car to bicycle is very difficult to predict. It evaluates the *maximum* energy savings that could be obtained through the increased use of the bicycle as a mode of transportation *to and from work*. It assumes that the mode shift to bicycles will occur for all automobile work trips 3 km or less in length. U.S. data [8] reveal that approximately 24.4% of automobile work trips fall under this range, with a mean distance of 2.25 km. Some longer trips could switch to bicycle use, but this is offset by the likelihood that some of the shortest trips (0.8 km) may be diverted to walking rather than bicycling. Therefore, the methodology estimates the uppermost limit of the range of savings. Some adjustment should be made for other use of the car left at home as well.

4.4.1 Data Input

- Identify the number of automobile work trips in the urban area (or community) that are 3 km or

less in length. Origin-destination survey information for the community (or data for a comparably sized community) should provide the desired data. Alternatively, it may be desirable to conduct a random telephone sample of households to obtain a distribution of trip lengths.

- Estimate the average bicycle trip length for work trips — where data are not available, a bicycle trip length of 2.25 to 2.4 km may be used. (The U.S. national average is reported to be 2.25 km.)
- Estimate the average annual automobile fuel-efficiency factor in litres per 100 kilometres. Use available Statistics Canada data.
- Identify the number of days that people will ride bicycles to work, taking climate and inclement weather into account.

4.4.2 Analysis Steps

The analysis procedure is as follows.

Step 1

Multiply the number of automobile-driver work trips in the urban area by the percentage of automobile work trips that are 3 km or less in length. This will yield the number of potential auto work trips diverting to bicycling per day. (Alternatively, obtain the number directly.)

Step 2

Multiply the number of diverted trips by the average bicycle trip length; this is the daily automobile VKT (veh-km travelled) eliminated from the roadway.

Step 3

Multiply the daily VKT eliminated by the number of days per year that a bicycle can be used as a mode of transportation to work (this factor should reflect climatic variation) to obtain the annual automobile VKT eliminated.

Step 4

Divide the annual VKT eliminated by the average provincial fuel-efficiency rate in litres per 100 kilometres to obtain the annual gasoline savings in litres.

Step 5 (Optional)

Adjust these savings to account for the VKT savings re-invested as travel by the car left at home. An average estimate can be reached by multiplying the savings by 0.60 to account for this new travel, assuming that 40% of the work travel is replaced by other travel. This yields the total annual *urban area* savings from bicycle actions.

Table 2.16 is a sample worksheet that could be used to estimate energy impacts, showing an illustrative problem and its solution [9].

The results shown in Table 2.16 must be carefully interpreted. First, they assume that a city-wide system of bicycle facilities will be provided; however, there is little experience as to what defines this system. Second, it is assumed that all driver trips of less than 3 km would change modes; there is no 'real world' documentation that this diversion would occur. Therefore, some reductions to reflect nondiverted cars are essential.

Table 2.16

Example Calculation of Maximum Energy Savings from Improved Bicycle Facilities

Assume that the Ottawa area implements extensive bicycle strategies, that 27.8% of all auto driver work trips are 3 km or less in length, and that the average bicycle trip length is 2.5 km.

1. Estimate the number of auto trips that are potential bicycle trips

   The number of auto driver work trips in the urban area is 243 752. If the percentage of trips that are 3 km or less is 27.8%, then the number of trips 3 km or less is 67 763 (243 752 × 27.8%).

2. Estimate daily vehicle-km traveled (VKT) eliminated

   If the average bicycle trip length is 2.5 km, then the daily VKT eliminated is 169 407.5 km (67 673 × 2.5 km).

3. Estimate fuel efficiency

   The average annual automobile efficiency is 6.3 km/L (use Ontario data).

4. Estimate daily gasoline saving

   Equivalent daily gasoline saving is 26 890 L (169 407.5 km ÷ 6.3 km/L).

5. Estimate annual gasoline saving

   The number of days per year that bicycle travel will occur is 178 days. The total annual gasoline saving is 4 786 420 L (26 890 L × 178 days).

   Taking into consideration a car-left-home factor of 0.6, the likely annual gasoline saving is 2 871 852 L (4 786 420 L × 0.6).

4.5 Implementation Experience

There is a 60-km network of exclusive bicycle paths within the Ottawa-Carleton Parkway System. The paths were built at an average cost of $16 000 per kilometre.

Figures 2.3, 2.4, and 2.5 demonstrate bicycle volumes found on approach routes to downtown in the south, east, and west corridors in August, 1979. Bi-directional, 12-hour (07:00 - 19:00) counts of 2905, 2653, and 1452 bicycles, respectively, crossed the screenlines. The distribution of trips shows the effect of distance on bicycle travel.

The potential for additional bicycle travel is shown in Figure 2.6. Even though the months of August and May are comparable for bicycle use, total bicycle volumes were nearly 100% higher during the OC Transpo strike. The ability to use bicycles

Figure 2.3

Bicycle Trip Volume and Distribution for the South Corridor, Ottawa-Carleton

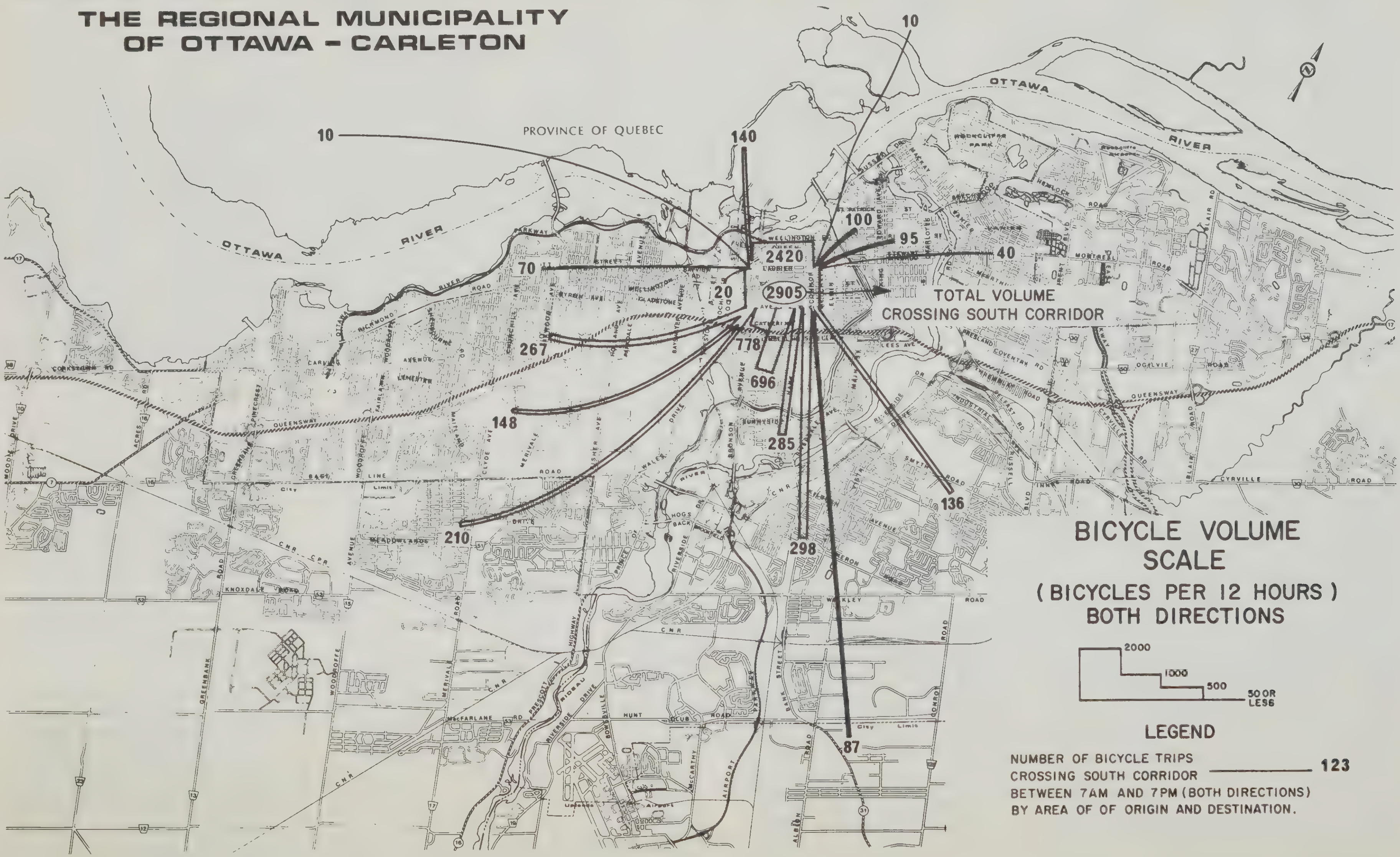


Figure 2.4

Bicycle Trip Volume and Distribution for the East Corridor, Ottawa-Carleton

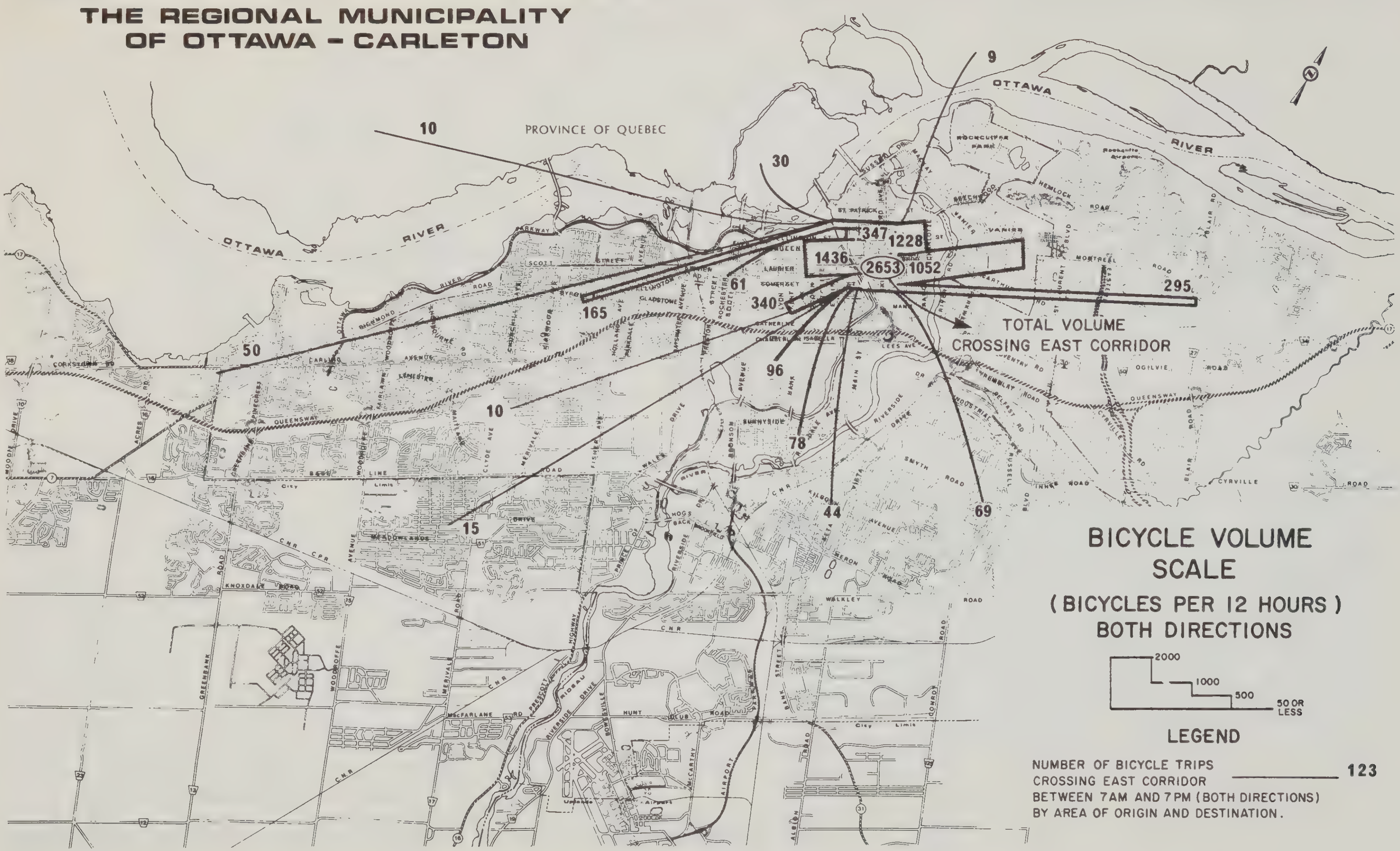
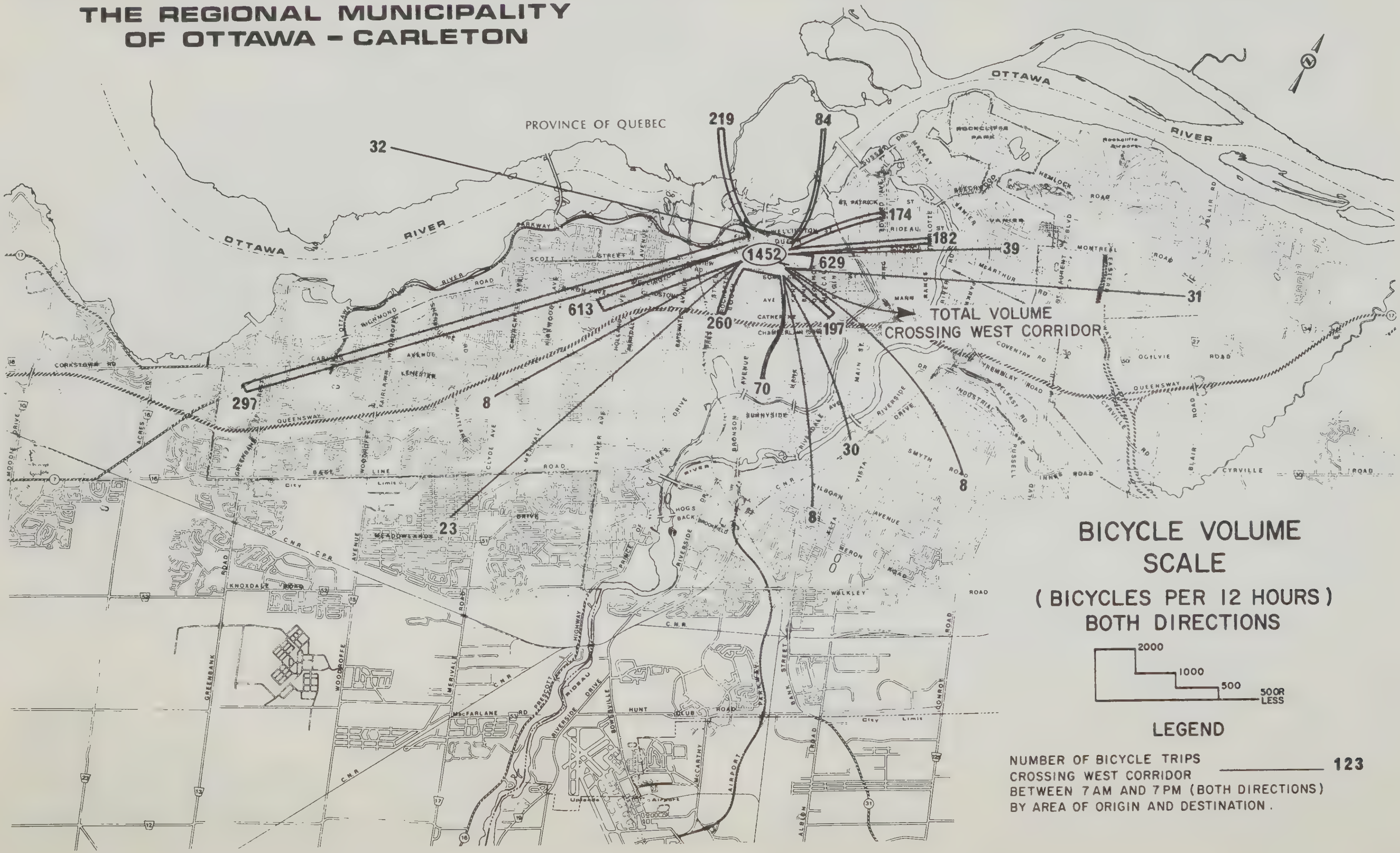


Figure 2.5
Bicycle Trip Volume and Distribution for the West Corridor, Ottawa-Carleton



as an alternative mode of travel demonstrates the desirability of promoting bicycle measures.

The work of the City of Toronto Cycling Committee over the past few years, conferences on urban bikeway planning, and work by related groups such as Cycling Toronto, the Ontario Cycling Association, and the Committee for Bicycles in Toronto, all point to an increasing demand and interest in cycling in Toronto. The Strok Report, completed in 1974, recommended an extensive Metropolitan network of recreational bicycle paths largely through the ravine system outside the City of Toronto. The 1977 Barton-Aschman report recommended a major east-west bicycle route along Wellesley and Harbord, serving the University of Toronto.

A number of bicycle routes are under construction, partly implemented, or under consideration (Eglinton Ave. W., ravine routes in Metro, Wellesley St., a portion of the east-west route, a major north-south route, Yonge Street, and a waterfront route in the City of Toronto). Scheduled events include a Public Bicycle Forum, Bicycle Picnics, Bicycle Week, and distribution of maps to schools and cycling groups.

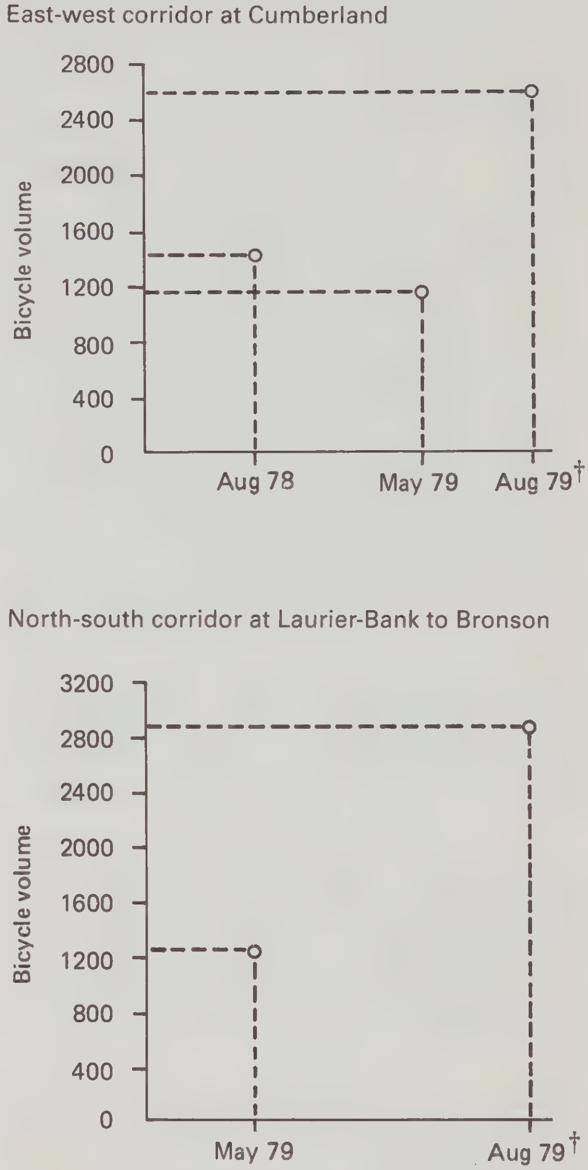
In spite of these activities and the interest in cycling, there are some specific fundamental difficulties in Toronto which have resulted in disjointed, fragmentary routes and delays in implementation of cycling facilities. Some of these are related to the physical characteristics of the city: climate, narrow rights-of-way, gradients, lack of support facilities such as bicycle parking in the Central Area, intersection conflicts, few underutilized corridors (such as railroads or Hydro tower lines) in the city, and major route discontinuities. Others result from an apparent lack of awareness of cyclists and how to deal with them on the part of motorists, together with a lack of awareness by cyclists of routes and facilities already available, and in some cases, little basic understanding of rules of the road and safe cycling operations.

The Québec Ministry of Transportation has instituted a three million dollar program over the past two years, funding 60 bicycle projects in 40 municipalities. About 80% of the budget is allocated to exclusive bikeways on separate rights-of-way, and the remainder to bicycle lanes on existing streets. The province funded 75% of the capital cost, while the municipalities paid the remaining 25% and are responsible for maintaining the facilities. This demonstration program is complete and is being evaluated this year. Some municipalities, notably Longueuil, have conducted some 'before-and-after' bicycle surveys to assist in the evaluation.

Bicycling is a significant travel mode in Europe, where the following bicycle use has been reported, expressed as a percentage of total trips.

Figure 2.6

Comparison of Corridor Bicycle Volumes*



*In Ottawa-Carleton, May to August 1979.
†During OC Transpo strike.

Copenhagen	17%
Upsala	20%
Stevenage	10%
Rotterdam	43%

It is interesting to note, however, that bicycle use in Rotterdam is expected to drop to 32% by 1990.

Bicycle use in the United States has been documented in a large number of studies. The Bicycle Institute of America estimates that 1%-2% of home/work trips are made by bicycle. Slightly more than 1% of the arriving passengers at BART stations arrive on bicycle [7]. An employee survey

Table 2.17
Bicycle Trip Frequency and Distance

Trip purpose	% of trips	% of km ridden	Trips/ month	Average length (km, one way)
Work and school	33	22	13.8	6.6
Recreation, touring	29	52	7.1	17.9
Utility	18	6	7.5	4.5
Exercise	16	13	9.1	8.2
Racing	4	6	9.3	16.1
Average			9.8	10.9

at the Salem, Oregon, Capital Mall area found 0.6% of employees using bicycles to get to work.

It would appear that bicycles might reasonably be expected to constitute from 0%-2% of total daily trips for non-recreational purposes. This percentage might be higher (5%-9%) in central business districts. Of course, with special situations such as colleges and universities, usage could be very high (18%-30%). School and recreational purposes dominate, and the frequency of use for non-recreational purposes is low — less than one trip daily.

Table 2.17 indicates the trip length and frequency of bicycle trips from a survey of regular cyclists. It is expected that the trips which are likely to be affected by a mode shift from autos may be shorter than the figures in the table indicate.

References – Bicycles

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[9] Trombly, J.W., S.L. Kupferman, and D.W. Boyle. *Draft Energy Impacts of Transportation System Management Actions.* 1 July 1981.

5 Pedestrian Facilities

5.1 Strategy and Objectives

Walking has limited scope as a replacement for auto travel because of the nature of urban travel. Long automobile trips cannot be replaced by walking because time is important, and the replacement of short trips does not add up to a large amount of energy savings. Nevertheless, as with bicycle facilities, improved pedestrian facilities would be supportive of energy conservation in general, and some auto fuel consumption could be eliminated.

5.2 Description of Measures

Transportation management actions to improve and encourage pedestrian travel include the following:

- sidewalk improvement,
- overpasses and underpasses,
- exclusive concourses for pedestrians,
- malls and auto-free zones.

Perhaps the best way to encourage pedestrian movements in high density centres is to provide separate walkways. These skywalks and concourses, such as are found in Toronto, Montreal, Calgary, Minneapolis, and Cincinnati, not only separate people from vehicles; they also encourage new commercial activity at the pedestrian level, although they sometimes reduce pedestrian flow past street-level shops.

Rededicating urban street space to pedestrian use creates a favourable pedestrian environment that often encourages shopping and social activities. Street amenities such as benches and trees or other plants help create a park-like atmosphere which enhances the surrounding area.

Like skywalks and concourses, malls generate new pedestrian trips, as well as reducing or re-orienting car movements.

The role of each facility will depend upon amount of pedestrian travel; conflicts with cars, trucks, and transit; necessary linkage to be provided, and land uses and physical factors. Toronto's underground concourse system stems from the need to connect the subway stations and Union Station with downtown offices and shops.

Pedestrian and pedestrian/transit streets normally require provisions for displaced street traffic: buses and street cars, service vehicles and goods delivery. In addition, there should be no parking garages along the street to be closed.

5.3 Effectiveness of Measures

Potential energy savings depend upon the number and length of auto-driver trips that would switch to pedestrian trips when improved facilities are provided. This involves estimating the lengths of walking trips (and car trips), as well as the proportion of car trips that would be diverted, in selected trip-length groups.

Pedestrian trips in city centres and neighbourhoods are generally short.

- In the United States, 1975 data indicate that 91% of all pedestrian trips to work were less than 1 mile long, whereas the mean distance to work by all modes was 8.5 miles [1].
- Surveys of pedestrian trip length in the Washington, D.C., Metropolitan area indicated that most pedestrian trips were less than one half mile; shopping and recreational trips accounted for over 60% of the total, as compared with about 5%-10% for work purposes [2,3].
- Studies of CBD working trips show that 85% of the people in larger cities usually walk less than 1000 feet [4].

The number, purpose, distance, and destinations of pedestrian trips will largely reflect the geographic characteristics of a locality. Characteristics such as residential and commercial activity patterns, terrain features, weather, and physical limitations will influence pedestrian travel.

Table 2.18 lists the effects of a number of pedestrian malls in the U.S. There was little change in vehicle-kilometres of travel, and hence in energy consumption, after the malls were built.

5.4 Evaluation of Energy Consumption

Automobile trips that are short in length will provide the greatest likelihood of a shift to walking. The methodology that follows assumes a 100% mode shift from auto trips less than 1.5 km in length to walking; thus it identifies the *maximum* gasoline savings that could possibly result

Table 2.18

Effectiveness of Pedestrian and Transit Malls

Name and location	Impact: Screenline traffic volume	Vehicle-km traveled	Transit ridership	Transit travel time	Transit service reliability	Retail sales	Other	Cost	Remarks
Salinas St. Mall Syracuse*		−0.5 (peak hour) +1.6 (peak hour in CBD)							
Church St. Mall Burlington VT†		+0.13							
Mid-America Mall Memphis TN†		+0.02							
Nicollat Transit Mall Minneapolis‡	Cordon counts, 290 500 before 274 000 after		No increase in overall ridership	No change	Better than on parallel streets. Standard deviation of trip times is 50–80% those on parallel streets	No evidence of increasing sales but Mall may have stabilized sales	Deliveries 49% impacted	\$5070/m \$367/m^2	No decline in auto trips to CBD
Chestnut St. Transit Mall Philadelphia‡	36 000 before 32 000 after		No increase in overall ridership	No change	Standard deviation of trip times 30–90% those on parallel streets			\$4333/m \$244/m^2	Some traffic adjacent to mall area seems to disappear
5th and 6th St. Malls Portland‡	336 300 entering or leaving CBD before, 369 100 entering or leaving CBD after; east–west screenline across Mall down about 20%		No increase in overall ridership	50% reduced		Turnover rate of stores increased, vacancy rate dropped		\$9000/m \$367/m^2	No real increase in peak volumes but improvement in pedestrian circulation. Sharp reduction in CO levels

*Rowan, N.J., D.C. Woods, and V.G. Stover. *Alternatives for Improving Urban Transportation — A Management Overview*. Prepared for the Federal Highway Administration by Texas Transportation Institute, Texas A & M University; October 1977.

†Wagner, F.A., and K. Gilbert. *Transportation System Management — An Assessment of Impacts*. Prepared by Alan M. Voorhees, Inc. for Urban Mass Transportation Administration; November 1978.

‡Edminister, M., and D. Koffman. *Streets for Pedestrians and Transit — An Evaluation of Three Transit Malls in the United States*. Prepared by Crain and Associates for Urban Mass Transportation Administration, UMTA-MA-06-0049-79-1; February 1979.

from pedestrian actions [5]. The computed savings resulting from this assumption should then be reduced to reflect the proportion of automobile trips that might actually shift. Each community will have a different reduction, depending upon specific local conditions.

The procedure requires each community to identify the trip purposes that are most likely to be affected by a particular action, and thus be most likely to shift to walking. Only these trip purposes should be considered.

Finally, it is assumed that the pedestrian facility improvement will affect the travel characteristics only within a 1.5 km radius. Only trips with origins and destinations within this area should be considered.

5.4.1 Data Inputs

- Identify the location, length, and influence area of the proposed pedestrian improvement.
- Identify the key trip purposes that would be most affected by the pedestrian improvement.
- Determine the total number of auto trips, by trip purpose, that occur within a 1.5 km radius of the pedestrian facility, with origins or destinations within the affected zone. Consider only trip lengths less than 1.5 km. (This input calls for some sort of trip matrix for the area by length and another by length and purpose.)
- Estimate the average pedestrian trip length. If no other estimate is available, 1 km may be used.
- Estimate the average annual automobile-fleet fuel-efficiency factor in L/100 km. Use available Statistics Canada data.
- Identify the number of days that pedestrian travel will occur: this calculation must take climate into consideration.

5.4.2 Analysis Steps

Step 1

Determine the travel data for the study area affected.

Step 2

Multiply the number of potential walk-trips per day by the average pedestrian trip length to obtain the vehicle-kilometres of travel eliminated daily.

Step 3

Multiply the eliminated VKT by the average fuel efficiency rate (L/100 km) to derive the daily gasoline savings in litres. This assumes that each

Table 2.19

Example Calculation of Maximum Energy Savings from Improved Pedestrian Facilities

1. Describe proposal (give sketch)
   The example used here is a pedestrian bridge and walkway, connecting the business district with a nearby commercial area.
2. Identify trip purposes
   The key trip purposes considered most affected by the pedestrian improvement are eating, shopping and working.
3. Estimate auto driver trips by purpose
   For each of the specified purposes, estimate the corresponding number of auto *driver* trips that are less than 1.6 km in length. These trips must be located within the given bounds of the affected area which is designated as within 1.6-km radius of the facility.

Trip purpose	Auto driver trips
Eat meal to work	227
Work to eat meal	227
Home to shop	140
Shop to home	140
Home to work	164
Work to home	298

4. Estimate the total auto driver trips
   Add the number of auto driver trips for each trip purpose above to obtain the total number of potential trips that will divert from auto to walking per day. Total auto driver trips = 1196.
5. Estimate the pedestrian trip length
   The average pedestrian trip length for this example is 0.8 km. If unknown, use 0.8 km as an approximation.
6. Estimate daily vehicle-km eliminated
   Daily vehicle-km eliminated = 1196 (step 4) × 0.8 km (step 5) = 957 km.
7. Estimate fuel efficiency
   The average annual automobile fuel efficiency is 6.3 km/L (use Ontario data).
8. Estimate daily gasoline savings
   Daily gasoline savings = 957 km (step 6) ÷ 6.3 km/L (step 7) = 152 L.
9. Estimate annual gasoline savings
   The number of days per year that pedestrian travel will occur is 178.
   Total annual gasoline savings = 152 L (step 8) × 178 = 27 056 L.
   An adjustment factor may be introduced for the proportion of driver trips that might remain. Use 1.0 as the maximum; lower factors should reflect judgement and situation specifics. Car-left-home factor is 0.6.
   Likely annual gasoline savings = 27 056 L × 0.6 = 16 233 L.

Table 2.20

Selected Pedestrian Schemes in Canada

	Calgary, Plus 15	Edmonton, Pedway	Halifax	Hamilton, Jackson Square	Kitchener, King Street	London, Elba Mall	Montreal, Underground	Ottawa	
								Bank Street	Sparks Street
A. General description									
Date of inception, implementation	1967, Jan 1970	1968, underway	1975–76, underway	1965, 1970	1965, 1978–79	1975, Sept 1976	1956, Sept 1962	1971, June 1972	1959, April 1960
Grade of System									
Above	×	×		×			×		
At		×	×		×	×	×	×	×
Under		×					×		
Dimensions	815 m average width by 900 m long	5 m wide, variable length, 2.7 m high	Various	—	5–6 m wide by 1170 m long	20 m wide by 210 m long	6 m wide by variable length	5.4 m wide by 12 blocks long	18 m wide by 6 blocks long
Total coverage upon completion (committed or proposed)	182 ha (60 blocks)	—	—	—	2.2 ha	0.43 ha	40 ha	0.9 ha	1.7 ha
Origination of scheme	City planners as part of master plan	City of Edmonton general plan	Business groups, city planners	Municipal politicians, city technical staff	Municipal politicians, city planners	East London Business Association	Developers, Metro system	Municipal and federal governments, business	Federal government, business
Funding of scheme	Developers		Federal, provincial, and city governments	Three levels of government, developers	Three levels of government	Municipal government, business, ratepayers	Private developers	Municipal and federal governments, ratepayers	Municipal government, business
Response of merchants									
Favourable	×	×	×	×		×			
Unfavourable					×				×
Security									
Local police	×		×	× (and plain clothes)	×	×		×	×
Television surveillance	×								
Security police	×						× (and Metro police)		

B. Planning aspects									
Surrounding land use									
Retail	×	×	×	×	×	×	×	×	×
Office	×	×	×	×	×	×	×	×	×
Institutional	×			×			×		
Residential	×			×					
Entertainment	×	×	×	×	×	×	×	×	×
Other		Public			Hotel		Hotel		
Reasons for pedestrianway construction									
Pollution	×	×							
Economics	×	×		×	×	×	×	×	×
Historic		×	×						
Congestion	×	×	×		×		×	×	
Aesthetics	×	×		×	×		×		
Environment	×	×	×	×	×		×		
City image						×	×		
Other	To integrate open space						Interlock metros		
C. Transport aspects									
Vehicles allowed									
None	×		×	×					
Emergency vehicles					×	×			×
Delivery vehicles					×		× (except carts)		×
Servicing vehicles					×	×			
Buses						×			
Taxis					×				
Non-motorized vehicles				×	×		×		×
District access to transit									
Local	×	×				×	×	×	×
Suburban		×				×		×	×

Source: M.M. Dillon, Ltd. *Non-Capital Intensive Transportation Options*. Prepared for the Winnipeg Tri-level Committee; October 1978.

person diverted was an auto driver. Thus, it provides an "upper limit" of fuel saved.

Step 4:

Multiply the daily savings by the number of days a year that pedestrian travel is possible, reflecting the weather factors. This is the total annual gasoline savings in litres attributable to a specific pedestrian strategy.

Table 2.19 gives a sample worksheet that could be used to estimate energy impacts and that describes an illustrative problem and its solution [5].

The suggested approach calls for available data on automobile patterns between parts of an urban area, and assumptions regarding the distribution of driver trip lengths by purpose, and the proportion of auto drivers attracted. Such data may not be readily available in many cities and are hard to synthesize. The probability of shifting, while hard to estimate, can be approximated by developing an upper-bound estimate that assumes a 100% diversion.

The example indicates that pedestrian facilities will contribute little, if at all, to energy conservation. However, encouraging pedestrian travel may be important for other reasons — such as revitalizing the city centre or attracting transit riders. Safe, convenient, and attractive pedestrian access to subway stations, bus and street car stops, and transfer points should be part of comprehensive transit projects [6]. The absence of such facilities may discourage transit riding and thereby increase energy consumption.

5.5 Implementation Experience

There are many examples of special pedestrian facilities in Canadian and American cities. Table 2.20 outlines characteristics of several pedestrian schemes in Canada.

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Ontario

Ministry of
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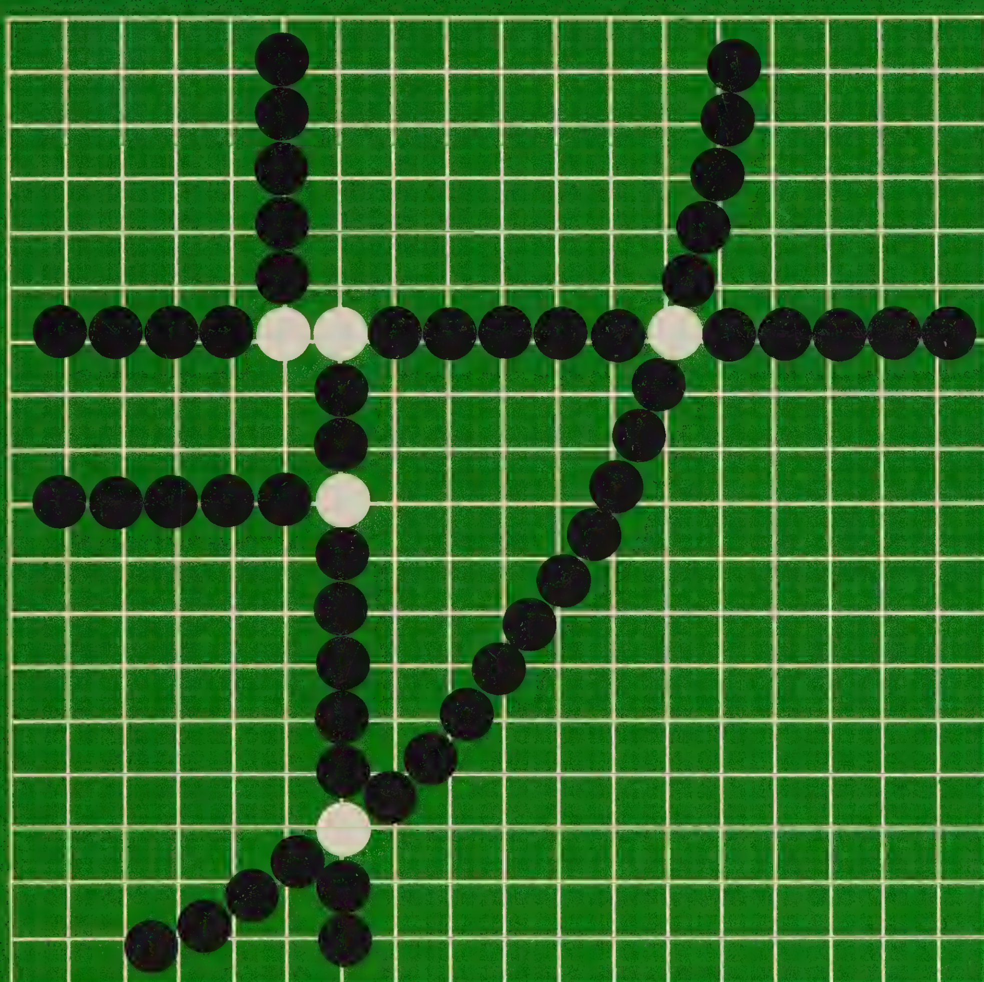
Transportation Energy Analysis Manual

3: Transit Service



The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM
Transportation Energy Analysis Manual

3:
Transit Service

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Preface

The purpose of the **Transportation Energy Analysis Manual (TEAM)** is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within their municipality. The Manual is organized into ten chapters, which outline the principal technical ways to conserve energy through transportation improvements.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is the crucial public-sector level because these decision-makers deal with the day-to-day activities of the citizens residing within their municipalities. Energy conservation is an ongoing, everyday affair, and the municipality is directly involved.

The **Transportation Energy Analysis Manual** will consist of chapters on the subject areas listed below. The Manual is being produced chapter by chapter as each is completed. These in turn will be updated as considered necessary.

Executive Summary
1. Program Overview
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Energy Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Program Management
10. Energy Analysis Methods

This chapter, Transit Service, focuses on and highlights the energy-conservation activities which are applicable for implementation in the operation of public transit services.

Additional information on the Manual or on any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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Figures

1 Introduction

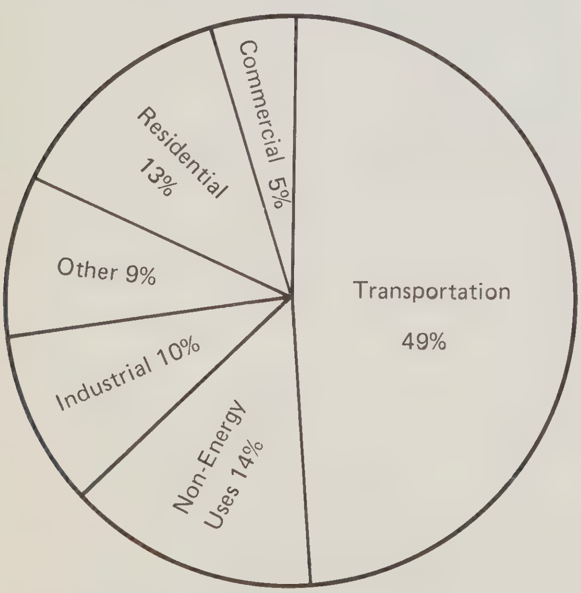
It is estimated that 49% of all refined-petroleum products consumed in Ontario are devoted to the transportation sector (Figure 3.1). Most significantly, the transportation sector is almost entirely dependent on petroleum products. The dependence of Canada upon foreign sources of oil underlies the adverse impact and cost of disruption of supply.

Distribution of energy use by mode and trip purpose is illustrated in Table 3.1. Automobile uses account for about 56%, urban public transit for less than 1% of all transportation energy consumed.

While most energy-conservation programs are directed at journeys-to-work, these work trips account for only a little over 20% of all transportation energy used. Thus, even countermeasures which reduce journey-to-work energy consumption by 25% could only bring about a reduction of a little over 5% in the total energy used. This underscores the importance of addressing all trip purposes in any strategy planning.

Figure 3.1

Refined Petroleum Product Consumption, Ontario 1979



Total, 1350 petajoules

SOURCE: Statistics Canada and Ontario Ministry of Energy.
Note: Other, refinery use and electricity generation; Non-energy, petrochemical feedstocks, lubrication oils and grease, asphalt, etc.

Table 3.1

Transportation Energy Consumption, Ontario 1979

Mode	Energy consumed: Equivalent barrels/day*	% of total
Freight	96 000	34.9
Passenger		
Automobile		55.5
Urban	101 000	36.8
Intercity	51 425	18.7
Bus		0.9
Urban	1 925	0.7
Intercity	2 475	0.2
Subway, street car, trolley	275	0.1
Rail		0.4
Urban	275	0.1
Intercity	1 110	0.3
Air	16 775	6.1
Other†	5 775	2.1
Total	277 035	100.0

SOURCE: Ontario Ministry of Energy.
* Energy has been converted to equivalent of crude oil.
† School bus, motorcycle, leisure vehicles, off-road vehicles, farmers' trucks and tractors.

Each energy-conservation measure carries with it an implicit ability to reduce overall energy consumption, and will fall within one or more of the following general categories. It will:

- reduce the number of vehicle-trips,
- improve energy-consumption characteristics of the vehicle,
- increase load factors,
- improve traffic flow.

Transit-system improvements will, for the most part, be in the first or third categories, removing an automobile-trip from the street system and increasing the load factor or number of person-trips per vehicle. Public transportation increases capacity in heavily travelled corridors and expands the person-trip capacity potential of freeway and arterial-street systems.

2 Opportunities for Energy Conservation

The diversion of single-occupant-automobile drivers to public transit is a viable energy-conservation technique. Most public-transportation *vehicles* consume more energy per *vehicle-kilometre* than do private automobiles; if higher load factors can be achieved, a lower level of fuel consumption on a *passenger-kilometre* basis can result.

Research has shown that the most effective way to increase transit ridership is through an improved level of transit service. At the same time, improvements through new technology and better maintenance and operating procedures conserve energy by increasing vehicle efficiency. Finally, traffic-flow improvements on the street (or by provision of separate facilities for transit) can reduce vehicle-hours of travel, providing benefits in both categories by improving transit service and vehicle operation. Street-system traffic-flow improvements are discussed in Chapter 2.

A significant portion of the population is "transit-dependent"; that is, its members have no alternative means of transportation. Still, the use of public transit today is a voluntary action on the part of most of the general public. Transit systems are faced with a high level of competition, due to increases in automobile ownership and auto-oriented land-use development and transportation systems. The following factors generally affect transit ridership — and are the factors that can be altered to increase transit usage.

- availability of transit service
- travel-time (including wait-time)
- frequency of service
- reliability and regularity
- fares
- comfort and convenience
- image or environment
- road congestion
- automobile ownership and cost
- parking availability and cost

The following factors affect vehicle and passenger-movement efficiency. Improvements can reduce fuel-consumption rates.

- vehicle size
- vehicle operation and maintenance
- transit-garage design
- alternative fuels

Table 3.2 illustrates several energy-conservation opportunities applicable to public transit. Although not all of the measures apply to every transit system, most measures do reflect good transit planning and operating procedures.

It is difficult to determine the specific amount of energy savings attributable to a particular transit-improvement measure. In some instances additional ridership will be generated, although it may be difficult to say how many are former automobile drivers. In other cases the action simply maintains the existing modal split (which might otherwise have changed as a result of improved auto-travel conditions). Those measures which reduce transit-vehicle travel can be translated into energy savings but this saving is usually small compared to the savings resulting from the removal of a private automobile from the road system.

Table 3.2

Energy Conservation Through Public Transit Actions

Transit action	Specific measures	Energy implications
Transit service expansion	• new routes • increased frequency • extended hours • special services	• reduces auto fuel consumption (modal shift) • increases transit fuel consumption (bus km)
Transit travel time reduction	• service integration • express/semi-express routes • exclusive bus lanes • transit vehicle priorities • timed transfers • fewer stops • fewer transfers • transit information	• reduces auto fuel consumption • reduces transit fuel consumption • improves transit vehicle fuel efficiency (L/100 km)
Route and schedule improvements	• proper route structure and spacing • improved schedule adherence • new scheduling techniques (computerized) • reduced deadhead and non-revenue km • reduced unused services	• reduces auto fuel consumption • increases load factors (passenger-km/bus-km) • reduces transit fuel consumption • improves transit vehicle fuel efficiency
Optimum vehicle size	• high capacity buses • standard buses • mini buses • paratransit	• increases load factors • improves person-trip fuel efficiency (passenger-km/L)
Fare programs	• monthly pass • employer programs • merchant discounts • fare integration • volume discount • honour system	• reduces auto fuel consumption • increases load factors
Transit marketing	• consumer and market research • service planning • transit promotion • customer service	• reduces auto fuel consumption
Vehicle operating and maintenance improvements	• improved maintenance • reduced vehicle idling • driver training	• improves transit vehicle fuel efficiency
Transit garage facilities	• location/design • construction materials • operational procedures • lighting type and level • heating type and level	• reduces transit energy consumption (building) • reduces transit vehicle fuel consumption
Alternative fuels	• electricity • propane • natural gas	• reduces gasoline and diesel consumption (vehicles) • reduces heating oil (buildings)
Land use planning	• increase residential/employment density along transit routes • integrated land use • improve subdivision/street layout • provide pedestrian walkways	• reduces auto fuel consumption • reduces transit fuel consumption • increases load factors

3 Conservation Actions

3.1 Transit-Service Expansion

The expansion of transit service provides the general public with an alternative (to the automobile) means of transportation. The potential for increase in transit ridership and reduced automobile fuel consumption depends on:

- the current efficiency of the transit system, and its coverage;
- the presence of concentrated travel corridors;
- levels of employment and residential densities;
- levels of personal income;
- the presence of high automobile travel costs, or other automobile disincentives such as traffic congestion or parking restrictions.

A number of specific measures are available to increase transit service in a municipality. These include:

- new routes,
- route extensions,
- more frequent service,
- evening/weekend service,
- special service.

The expansion of transit service offers the transit rider a wider choice and will encourage a modal shift from the automobile. However, this strategy will require additional transit vehicles and manpower, and the additional service will also consume more fuel. Careful evaluation is necessary to ensure that the strategy saves more energy than it uses.

3.2 Transit Travel-Time Reduction

Transit travel-time can be viewed from two perspectives. The first perspective, that of the transit-system operator, includes two travel-time variables:

- the dwell-time at the stop,
- the travel-time on route segments.

The second perspective, that of the user, is much more complex, consisting of six potential travel-time variables:

- travel-time to the bus stops or terminal;
- wait-time;
- loading and fare-collection time;
- bus trip-time (comprised of segment travel-time and stop dwell-time);
- transit unloading-time;
- travel-time to destination.

While there is a great degree of commonality, the analytic approaches are significantly different. The operator's view of transit travel-time is used to determine the level of operating efficiency of the system. The user's view, on the other hand, is necessary to determine the appropriate areas where transit-vehicle speed and travel-time improvements could encourage an increase in transit ridership and hence a reduction in automobile use and fuel consumption.

Increases in bus operating speeds, through improved vehicular flow and reduced numbers of stop-and-go situations, can reduce transit fuel consumption. In some cases, it may be possible to reduce overall vehicle requirements and still maintain established headways. Every transit vehicle saved represents a significant energy and financial savings to the municipality.

The faster, more attractive ride provided by the higher, more consistent transit operating speeds can encourage new transit ridership. If this new transit ridership can be diverted from the automobile mode, the overall region-wide energy consumption can be reduced.

There are a number of ways to improve transit vehicle flow. Those strategies for street improvement generally applicable to all vehicles are discussed in more detail in Chapter 2 of the Manual. In addition there are a number of measures available which relate directly to transit operations.

The measures recommended for improving transit vehicle speeds include:

- transit-priority signal pre-emption,
- reserved transit lanes,
- express transit service,
- reduced dwell-time,
- reduced numbers of bus stops,
- traffic-flow improvements.

Transit-Priority Signal Pre-emption — Transit-priority signal systems involve the pre-emption of a normal signal cycle to permit buses to progress with minimal delay. This may be accomplished by

a street-located sensor or an on-board transmitter. Once the transit vehicle has completed passenger loading and is ready to proceed, the operator can activate the traffic signal to recall or extend the green phase for a predetermined time.

The pre-emption should normally be carried out within the basic signal cycle to retain the normal traffic progression, or signal coordination, on both streets. In special situations and at isolated intersections, however, it may be feasible to give transit priority upon arrival.

There may also be some cases where transit vehicles can be exempted from a right- or left-turn prohibition at signalized intersections. Special signal phases may also be provided to help transit vehicles complete their turns with minimal delay.

Transit-actuated signals may sometimes increase the overall delay and energy consumption of other vehicular traffic. In each case, it will be necessary to calculate the time and energy savings for transit vehicles using the signals and to compare this with the increase in delay and energy consumption for other vehicles on the street.

Reserved Transit Lanes — Reserved transit lanes or "transit only" streets serve to separate transit vehicles from other traffic. In appropriate instances, this can reduce person-delay, improve transit operating speed and attractiveness, and reduce transit operating costs and vehicle requirements. The use of the lane or street does not have to be restricted to transit vehicles: other multi-occupancy vehicles such as car pools, van pools, and/or taxis could be permitted, at the discretion of the municipality. However, this should not be so general as to restrict the effectiveness of transit operations or to render enforcement impossible.

The reserved-lane concept need not be restricted to extended sections of roadway. In fact, there may be localized areas of congestion and traffic bottlenecks where a short reserved or bypass lane could be implemented to improve transit operations and travel-time.

The Province of Ontario has recently extended the transit capital subsidy-assistance program to include reserved transit lanes, provided that satisfactory justification for the facility and clear documentation of its transit orientation are established. This justification is to be in financial terms and must establish that the benefits to transit, such as schedule-time savings, ridership and revenue impact, operating-cost reductions, improved vehicle utilization, etc., will be sufficient to warrant the expenditure.

From an energy perspective, overall VKT (vehicle-kilometres travelled) might be reduced if transit were thus able to attract passengers who would otherwise have travelled by car. Sufficient street capacity generally should be available for displaced automobiles and trucks to prevent increased congestion and fuel consumption.

A number of reserved transit lanes have been implemented in Toronto, Ottawa, and other North American cities. Although these lanes are usually found in larger cities, specialized applications at local congestion spots may be practical in smaller urban areas as well.

Express Bus Service — Express bus service decreases bus travel-time through the elimination of intermediate or local stops. Depending on the number of stops, express service may significantly reduce total travel-time and thereby attract new riders.

A valuable adjunct to express bus service is the provision of commuter park-and-ride facilities. These may make use of existing lots, such as at stadiums or shopping malls, or they may be specially built. "Park-and-ride" facilities have been greeted with growing enthusiasm because they offer new tangible transportation service and focal points for ridesharing programs as well as for bus service.

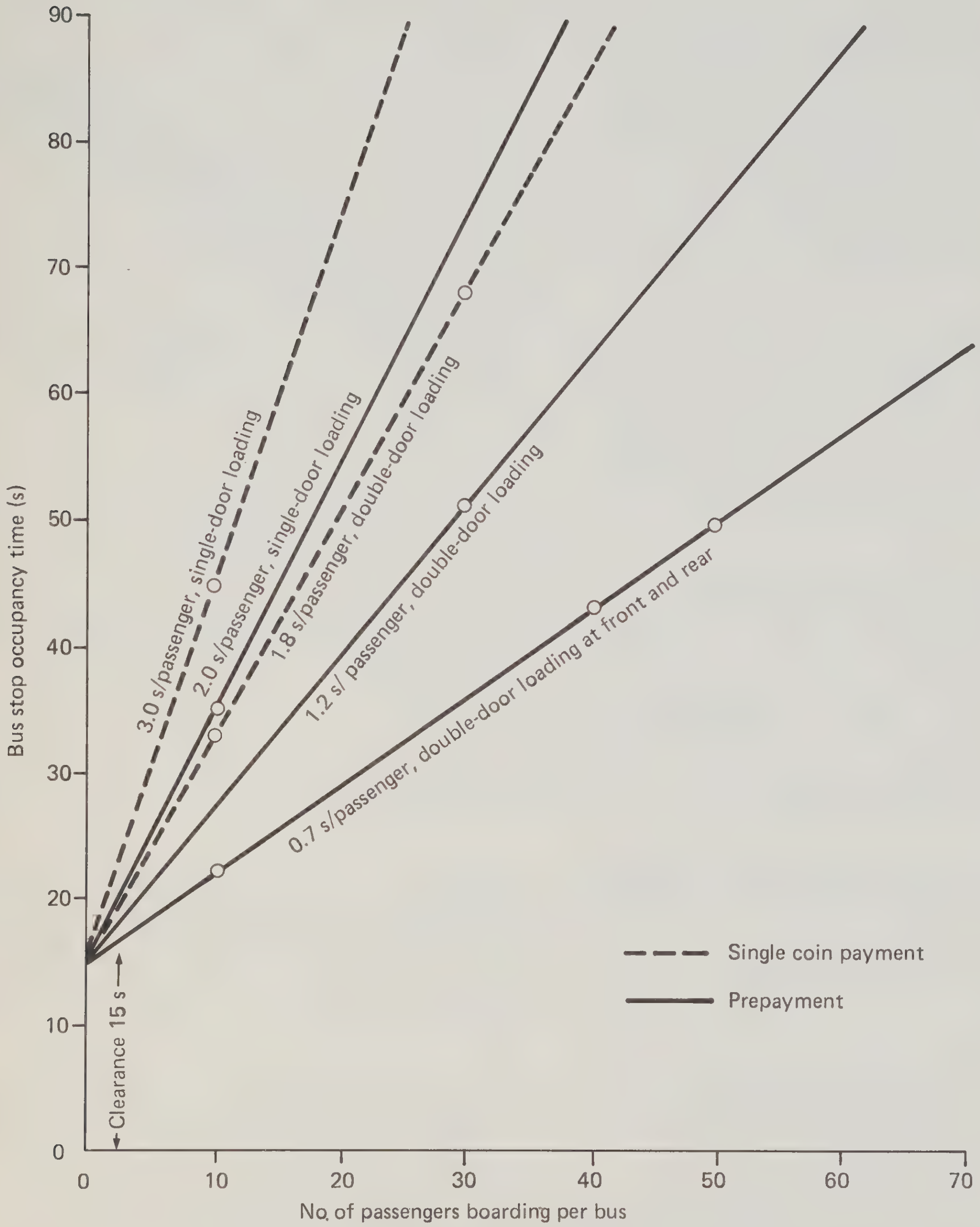
Ottawa is an excellent example of the application of express bus service incorporating both express and limited-stop service: approximately 27 000 vehicle-kilometres are offered, along 38 routes, using 183 buses, and carrying 30 000 daily peak-period trips. Interlining, which is a technique of scheduling vehicles for two or more routes to maximize vehicle utilization, has been used to reduce the total number of buses required to operate the service.

Ottawa's express bus service obtains an average system-speed of 29 km/h (compared to regular peak service of 18 km/h), an improvement of 33%. Ottawa-Carleton has combined its express services with bus priority techniques and preferential treatments: arterial "with-flow" bus lanes, exclusive bus lanes on an urban parkway, and a number of locations which allow priority turns.

Reduced Dwell-Time — Bus dwell-times are affected by the design of the vehicle and the method of fare collection (as shown in Figure 3.2). Moving from an exact-cash fare payment to monthly passes or prepaid boarding areas reduces dwell-time. In addition, the characteristics of the bus and fare-collection system, (single-door or double-door), have a dramatic impact on the boarding (loading) time and, therefore, the dwell-time. A number of fare-payment options are discussed later in Section 3.6.

Reduced Number of Bus Stops — Reducing the number of bus stops per kilometre is another means of increasing bus operating-speed and reducing fuel consumption. Consideration should be given to reducing the number of stops where

Figure 3.2
Bus Transit Dwell Time



SOURCE: Wilbur Smith and Associates. *Bus Use of Highways — Planning and Design Guidelines.* Transportation Research Board, NCHRP; 1975. No. 155.

headways are short (less than 10 minutes). In some cases, it may be feasible to skip stops, especially if high load factors are experienced. Figure 3.5 illustrates the impact of walk-time to the bus stop on potential transit ridership.

Figure 3.3 illustrates the speeds that are possible, given the number of stops per kilometre. The difference between the bus-expressway and arterial-expressway curves are explained by the greater peak speeds attainable when stops are few and access is controlled. Figure 3.4 shows how fuel consumption increases with a rise in number of stops per kilometre. Reducing the number of stops per kilometre from seven to five can result in about a 20% saving in fuel consumption.

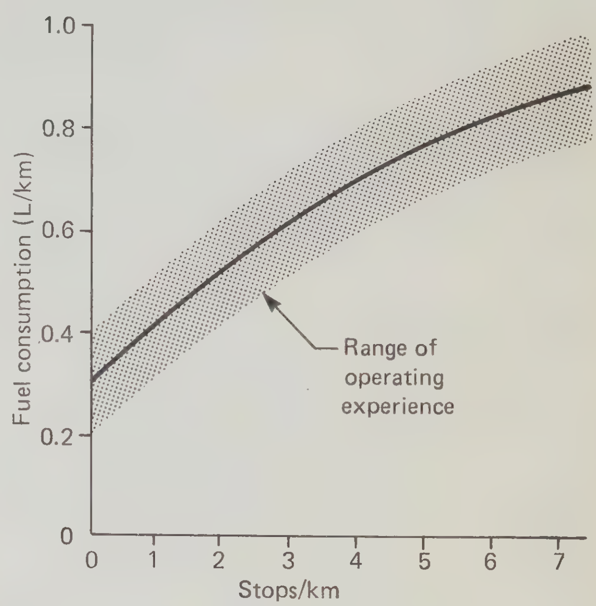
Traffic-Flow Improvements — Traffic-flow improvements, by reducing delays on the street system, will also benefit transit service on the street. In some cases, however, major new road facilities may induce new vehicular trips. Such improvements should be reassessed to determine their net energy savings or losses. This measure is discussed in more detail in Chapter 2.

3.3 Routing and Scheduling

The public expects bus service to be dependable and timely. The use of transit for those trip purposes which are non-routine or for non-work purposes will be influenced by the dependability of the transit system. People with a mode choice (auto versus transit) will not use transit if the service is perceived to have poor schedule adherence and inconvenient routing.

Figure 3.4

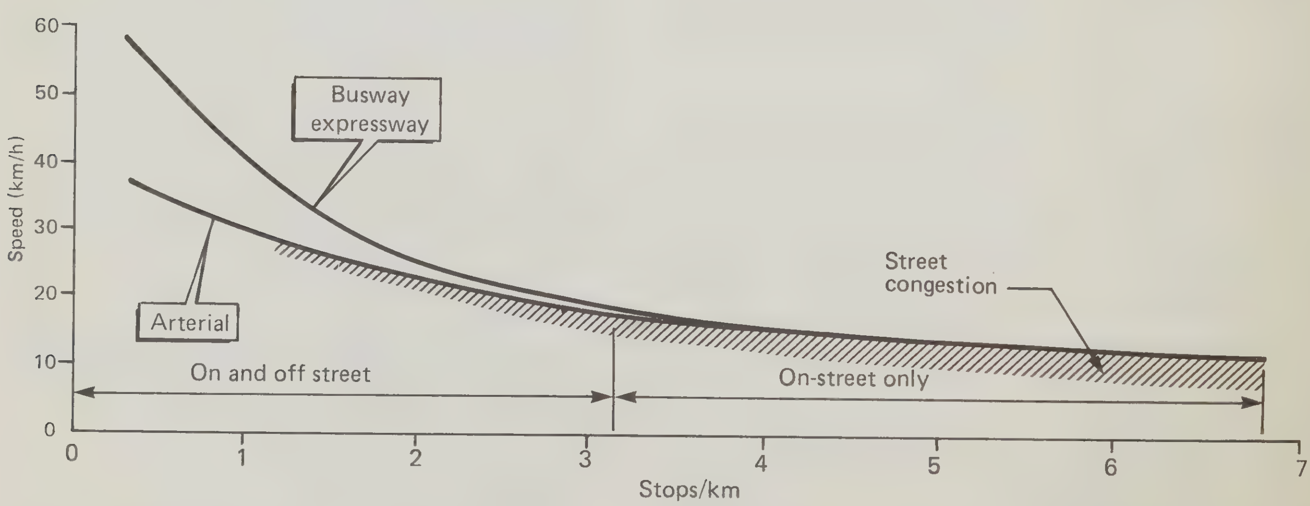
Diesel Fuel Consumed Versus Bus Stop Frequency



Source: Wilbur Smith and Associates. *Metropolitan Toronto Area Transportation Energy Study.* March 1981. NCHRP III and Caltrans report.

Figure 3.3

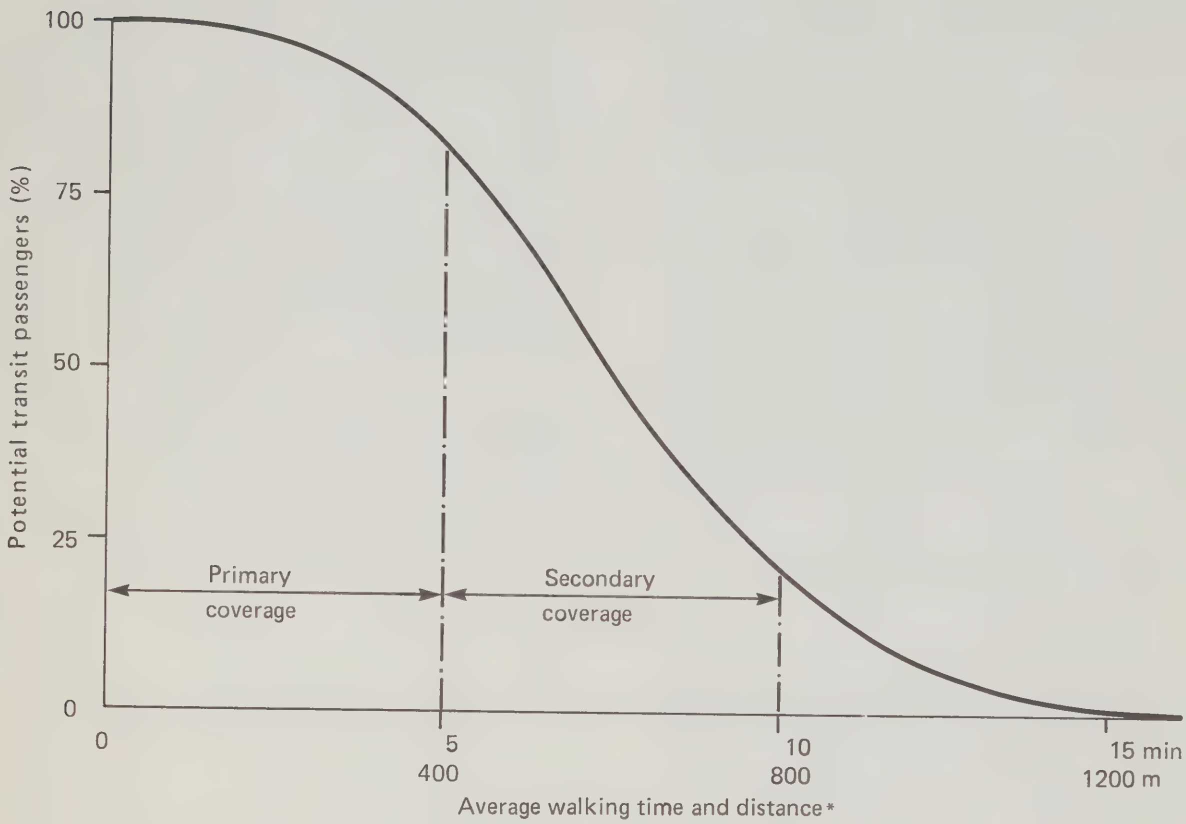
Bus Speeds in Relation to Stop Frequency



Source: Wilbur Smith and Associates. *Bus Rapid Transit Options for Densely Developed Areas.* U.S. DOT, FHWA; February 1975.

Figure 3.5

Transit Usage as a Function of Walking Time and Distance from Route



SOURCE: Dillon, Ltd. *Non-Capital Intensive Transportation Options.* Prepared for the Winnipeg Tri-Level Committee on Urban Affairs; October 1980.
* Average person.

Routes and frequencies should reflect service-planning guidelines relative to load factors and policy headways. Redundant or poorly used routes should be monitored for possible service changes, reductions, or elimination. An empty bus produces neither revenue nor energy advantages.

Routing — As the walking distance from a transit stop increases, the potential attractiveness to transit riders falls off. As illustrated in Figure 3.5, the majority of potential transit riders will walk up to 400 metres (5 min) to the transit route, while very few riders will walk more than 800 metres (10 min).

Bus routes must effectively penetrate neighbourhoods, with minimum circuity. If routes are placed too far apart, walking distances become too great and public transit will be unattractive to many residents. If routes are too close together, service duplication will result. With ridership split between two routes, bus utilization becomes inefficient. Routes which converge on activity centres or run along the same street may be good candidates for stop-skipping or other alternative service modifications to reduce travel-time.

Routes should also be structured to service major travel corridors effectively. Routing should be as direct as possible, with a minimum number of transfers.

Scheduling — In evaluating schedule adherence, the following steps should be taken.

- Inventory schedule adherence on each route at major stops, during various days, weather conditions, and times.
- Compare actual travel-time to schedule-time, and identify the reasons for any deviations or problems.
- Make appropriate modifications to schedules.

As a transit system increases in size, so does the time required for establishing vehicle schedules and driver assignments. Although routes and schedules usually have a strong historic background, there may be a need to provide dynamic modifications.

RUCUS, an acronym for "run-cutting and scheduling," is a computer package developed in 1970 by the Mitre Corporation under sponsorship by the Urban Mass Transportation Administration (UMTA) of the U.S. Department of Transportation (DOT). RUCUS is presently in varying stages of implementation in 25 transit properties in Canada and the U.S.

Once schedules have been established and routes defined, it is necessary to monitor bus movements. The MTC has been involved with demonstrating transit-control and -information systems (TCIS) throughout Ontario. The basic purpose of TCIS is to communicate with the transit vehicles on the street, to monitor and control system performance, and to report this performance for management-information purposes. The information gained can help to reduce the number of buses needed or, conversely, can allow for improvement in the level of the service provided.

3.4 Computerized Transit-Information Systems

The Ontario Energy Corporation, in a joint venture with Teleride Corporation, is supporting the development and marketing of computerized transit-information systems. The objectives of the Teleride system relate directly to improved rider confidence, reduced passenger wait-time, and increased ridership.

The system increases the attractiveness of public transit by providng the potential transit rider with telephone information concerning the arrival time of buses at a particular bus stop. The availability of this information reduces the wait-time at bus stops, a feature which is especially welcome at night or during inclement weather.

Computerized transit-information systems have been installed in Mississauga and Ottawa. Similar systems are currently being implemented in Toronto, Kitchener, Waterloo, Brantford, and Guelph.

The system implemented in Mississauga has increased transit ridership and improved transit operating performance overall. Generally, a transit rider who utilizes the system waits approximately 5-8 minutes for a bus. This is a reduction of 2-3 minutes from the normal wait-time. First-year ridership on routes where the system has been implemented increased an average of 10-13% and ridership continued to increase in the second year.

The Mississauga system also has facilities for the controllers (inspectors) to observe continuously the location and status (in service, out of service, emergency, etc.) of the buses equipped with mobile terminals and radios. The system includes data-logging and analysis programs for producing transit management reports.

3.5 Optimum Vehicle Selection

Transit-Vehicle Size — Significant energy savings may be realized by either increasing or decreasing the size of transit vehicles, depending on basic route-demand and system characteristics. In general, buses offer a trade-off: small ones consume less fuel, but have a lower overall seating capacity; large buses, though they consume more fuel, can carry more passengers per bus.

It is desirable to use small buses on low-demand routes or during off-peak periods, and in areas where a great degree of manoeuvrability and flexibility is desired.

A survey conducted in 1981 revealed the following fuel consumption rates for various bus makes and sizes in 18 Canadian transit systems.

	Fuel-consumption rate (L/100 km) for bus length:		
Bus make	9.2 m	10.7 m	12.2 m
GMC	33.5 (26.9–45.5)*	52.0 (47.0–59.2)	56.3 (50.4–70.5)
Flyer		60.6	60.0 (54.4–65.6)
Orion	39.7 (34.4–42.7)	43.4	

SOURCE: Ontario Urban Transit Association, Ministry of Transportation and Communications Subcommittee on Alternative Fuels and Fuel Economy Improvement Measures.

*Average followed by range in parentheses.

High-Capacity Buses — High-capacity buses trade off increases in vehicular fuel consumption against increases in passenger capacity. The capacity may be achieved by adding an extra level (double decker) or by lengthening the vehicle (articulated). Double-decker buses generally carry 20-25% more passengers than a standard bus, while articulated buses may carry 40-60% more. In some cases, it may be possible to substitute two articulated buses for three standard ones.

High-capacity buses may necessitate the redesigning of bus stops, bus bays, terminals, etc.; changes to maintenance facilities; and/or training of staff. Per-vehicle maintenance and operations costs will also increase. High-capacity buses may also provide an opportunity to introduce alternative fare-collection methods to improve overall operations.

In general, the use of higher-capacity buses may be warranted where capacity requirements exceed 500 passengers per hour in the peak direction; where high-density local routes have head-

ways of 8-10 minutes or less; and where high-density, peak-hour express routes have close headways and large numbers of standees.

General Motors is building 53 articulated buses under contract to the Province of Ontario, for delivery in 1982. These vehicles will be tested in Hamilton, Mississauga, Ottawa, and Toronto.

Shared-Ride Taxi — In many municipalities where transit ridership is low, there may be an opportunity to replace standard transit vehicles with vans or taxicabs.

Taxis represent an underutilized transportation resource in many urban areas. In most cases, the exclusive-ride feature and the extensive deadheading, cruising, and idling results in an energy-inefficient operation. However, taxis operating in a shared-ride mode can, in certain instances, provide an energy-efficient and cost-effective transportation alternative to the private automobile, exclusive-ride taxi or fixed-route transit service. It is essential that a shared-ride taxi service support and complement the fixed-route transit system; it must not compete with it.

There may be opportunities during off-peak periods or in low-density residential areas to replace the conventional fixed-route transit system with either a fixed-route taxi service or a demand-responsive taxi feeder service connecting to major transit routes or activity centres. These smaller vehicles, which consume less fuel than buses, may be converted to either diesel or propane to effect even greater savings.

Table 3.3 summarizes operating experiences of *Dial-a-Bus* and shared-ride taxi systems.

Since 1974, a shared-ride taxi service has been operating in Peterborough, Ontario. This system, like Dial-a-Bus, was designed to provide public transportation in low-population-density areas, with the important difference that it uses local taxicabs rather than mini-buses. Initiated in the Kawartha Heights suburb of Peterborough in May, 1974, it was an immediate success and was expanded to include the southwest sector of the city just three months later.

For 10 cents plus regular bus fare, passengers are picked up at their homes and taken to a pre-

Table 3.3

Comparison of Characteristics of Dial-a-Bus and Shared-Ride Taxi Systems

Characteristics	Dial-a-bus			Shared-ride taxi		
	Median	Range	*n**	Median	Range	*n**
Service area						
Size (km^2)	19.7	4.1–8733	50	29.5	10–391	28
Population ('000)	18.0	2.1–244	50	34.2	10.5–315	28
Population density (persons/km^2)	795	4–7233	50	1587	324–5204	28
System						
No. of vehicles	4.6	1–18	50	5.8	1–75	28
No. of employees	8.8	1–29	27	8.2	5–165	8
Hours of service/day	11.9	6–24	45	12.0	7–24	26
Annual veh.-h ('000)	8.8	1.6–63.3	38	11.9	2.1–44.4	22
Annual veh.-km ('000)	233.3	29–1353	37	247.5	42–1274	17
Weekday ridership	206	14–1000	50	260	20–3200	28
Person-trips/1000 pop. per day	9.8	0.81–65.2	50	4.3	0.98–27.6	28
Person-trips/km^2 per h	0.9	0.002–6.4	45	0.5	0.07–1.9	26
Trip length (km)	2.98	0.8–15.3	12	4.10	1.3–6.0	12
Ride time (min)	14.8	7–30	23	10.2	1–20	11
Actual wait time (min)	15.0	5–37	21	15.0	2–27	16
Passengers/veh.-h	5.86	1.8–11.0	38	5.49	2.8–8.7	22
Passengers/veh.-km	0.29	0.05–0.58	37	0.29	0.14–0.46	17
Costs†						
Fare ($)	0.50	0–2.00	40	0.50	0.15–1.00	21
Cost/passenger ($)	1.82	0.85–4.47	35	1.70	1.05–2.94	11
Revenue/passenger ($)	0.29	0.21–0.59	10	0.45	0.37–0.92	6
Cost/veh.-h ($)	10.00	5.14–22.04	31	9.95	8.97–14.65	11
Driver's wage ($/h)	4.00	3–5.67	13	3.35	2.8–4.0	10
Driver's fringe benefits (%)	24	15–40	7	22.5	20–24	4

Source: Paratransit Handbook, U.S. DOT; February 1979

**n*, number of systems sampled.

†All costs are in U.S. dollars

determined transfer point outside the suburb, where they board a fixed-route bus and continue to their destination. On the way home, they transfer from the bus to a cab. Passengers telephone for *Trans-Cab* service from their homes.

The taxi company providing Trans-Cab service works under contract to the Peterborough Transit System and uses its own existing taxicab fleet. When its cabs are not in public-transit use, they go about their normal business, picking up regular fares.

3.6 Fare Programs

One of the most direct influences on the choice between auto and transit is out-of-pocket cost. Fare programs may either allow for wholesale or specialized reduction in fare or provide for prepayment or increased convenience in payment. Programs which allow for wholesale or selective fare reductions will generally have the effect of increasing ridership, while programs which provide for fare prepayment without significant fare reduction will, in general, result in improved operations through reductions in dwell-time.

A number of fare programs are possible:

- monthly pass,
- peak/off-peak fare differential,
- fare discounts (employer, merchant, general),
- fare-by-distance,
- fare integration between systems,
- honour fare.

Monthly Pass — Prepaid-transit-pass programs are intended to encourage transit use by making public transit easier and more convenient to use. Transit riders purchase the pass once a month and simply show it to the driver upon boarding. Since boarding the transit vehicle is faster, the overall transit travel-time is reduced.

Pass programs are mostly used by the regular transit patron; they are not likely to change peak-hour ridership substantially. In many cases, pass holders take additional trips during the off-peak which they might not have otherwise taken, but it is difficult to say whether the implementation of a pass program will reduce automobile use.

Because most of the pass users are regular transit users, it is essential that the pass be priced properly. If the price is too low, large losses in revenue will occur.

Peak/Off-Peak Fare Differential — In most transit systems, the peak periods account for a large share of daily ridership. Introducing a higher fare during the peak period can cause some transit passengers to travel during the off-peak rather than the peak period. The lower off-peak fare may eventually also serve to attract some additional passengers.

Additional off-peak ridership can, in most cases, be accommodated by the existing transit service without additional vehicles. In some cases, peak-period ridership may decrease enough to permit a slight reduction of service requirements and level out vehicle assignment. On the other hand, because of the higher peak-period fare, there may be a tendency for some passengers to shift back to their automobile. Optimally, additional ridership attracted to the off-peak period would be sufficient to offset any loss of peak-period riders.

The introduction of a peak/off-peak fare differential may complicate transit operations, and there might be some confusion on the part of the general public as to when the different fare levels apply. However, this option could promote a more efficient use of transit, shifting some peak-period riders to off-peak hours.

Fare Discounts — Many transit systems offer discounts from the regular adult fare for senior citizens, students, and children. Although further discounts would probably increase transit ridership, the overall revenue of the system would decrease. It is generally accepted that transit fares must be maintained at a level such that users of the system pay their share.

There are, however, other options, such as employer and merchant discounts which can be used to encourage transit ridership. These programs involve the purchase by the employer or the merchant of transit fares at the regular price. These are then passed along to their employees or customers at a discount. In some cases, the merchants may join together to purchase the transit system for a day or a portion of a day to allow the public to ride free (e.g., for Christmas shopping).

Fare-by-Distance — Under this option, transit riders would pay a higher fare for long trips than for short trips. The passengers would be responsible for purchasing and having in their possession a valid ticket or receipt covering the total trip and would be required to provide proof of fare paid. Its use would be suited to operations that use the honour system of fare collection, or systems that have a limited number of easily controlled stations. In general, this option would encourage short trips and discourage long ones. There may be some cases where the public would shift back to the automobile for those longer trips, however.

This measure would have a major impact on transit operations and the procedure would become more complex. The general public would have to calculate their fare and obtain and carry a receipt as proof of payment. The impact of this type of fare is likely to be greatest on the occasional or first-time user.

Fare Integration Between Systems — In many urban areas there are separate transit systems operating in adjacent municipalities; to travel from one municipality to the other, it is necessary to transfer between systems and pay a second fare. To encourage ridership between adjacent urban areas, a fare-integration system can be implemented.

Fare integration involves the purchase of one fare (cash, ticket, pass) which allows the passenger to travel on both transit systems. The price of the fare could be equivalent to the total of the two systems' individual fares, or a discounted value could apply. In most cases, a fare discount is offered and this, together with the added convenience of having to pay only once, encourages an increase in transit ridership.

GO Transit, which operates commuter bus and rail services in the Toronto area, has, over the past two years, experimented with fare integration in conjunction with two municipal bus systems (Brampton and Oakville). The integrated system encourages passengers to use the local transit system instead of automobiles to travel between their homes and the GO Rail stations located within the municipality. Passengers are allowed to board the local transit system free of charge, provided they have a valid GO Rail ticket or pass. Initial results indicate that this fare-integration system has been successful in increasing transit ridership. During the first nine months of the project, the number of passengers travelling to or from the Go Rail station via the local transit system increased by about 100 000 (34%) in Oakville alone.

At the present time, the fare-integration system applies only to the GO Rail system. However, the success of the project has prompted GO Transit officials to investigate the expansion of fare integration to other municipalities, and the inclusion of the GO Bus system.

Honour Fare — The honour-fare system, used extensively in parts of Europe, requires each passenger to be responsible for purchasing and having in his possession a valid ticket or receipt. The passenger must be able to prove, if asked by an inspector, that he has paid the appropriate fare.

The major advantage of the honour-fare system is that the faster boarding time reduces the time a bus is stopped. This leads to shorter travel-times, which improve the fuel efficiency of transit vehicles and encourage ridership increases.

To date, honour fare has not been implemented in Ontario, although the Provincial Government has completed a study and is designing a trial system for testing in Ottawa. Various elements of honour fare have recently been implemented in Calgary, Edmonton, and Vancouver.

3.7 Transit Marketing

Many communities think of transit marketing as a new system logo or flashy paint job; in reality, transit marketing should be a carefully organized program, designed to identify the transit riders' needs and preferences, and to develop transit service to accommodate these requirements. The transit-marketing cycle shown in Figure 3.6 details product, price, and promotion, all centred on the needs of existing and potential riders. Primary marketing objectives are:

- to promote the image and identity of the transit service;
- to inform the public of available services;
- to target service which best benefits the operator, passenger, and community;
- to provide basic information regarding system characteristics and performance, for use by management in promoting the transit service.

An effective transit-marketing program should be implemented not only to affect immediate ridership, but also to ensure that an adequate basis for future transit operation is developed. The major elements are:

- market research,
- service planning,
- transit promotion,
- customer services.

Market Research — The basis of an effective marketing program is market research. This provides management with information on the basic characteristics and transportation requirements of the municipality.

The basic information required includes:

- demographic data regarding the population;
- travel-behaviour patterns of the population;
- auto-ownership and -use data;
- profiles of the elderly and handicapped segment of the population;
- transportation needs of the community;
- budget and expenditures of the transit system;
- attitudes and opinions of the population about transit issues and transit-system utilization.

Service Planning — Once the characteristics and requirements of the urban area have been identified, the next step is to develop or modify the transit service plan. This function, generally carried out by the transit planning department, involves the establishment of service standards based on market characteristics and the municipal financial and service objectives. The establishment of service standards requires decisions in the following areas:

- route structure,
- maximum headway,
- hours of service,
- fare structure,
- special services,
- minimum load factors.

Transit Promotion — The third aspect of market research is transit promotion. The main objectives of transit promotion are to increase public awareness, reinforce positive attitudes of present riders, and encourage a modal shift away from the automobile. The major task is to convince the public that public transit is a cost-effective and energy-efficient alternative to the automobile (single-occupant) and that in many cases, the use of transit can assist in the reduction of traffic congestion.

There are many ways in which municipalities can promote transit. One of the most common is through the employees, particularly the drivers. These employees are in daily contact with the public and represent a system-wide sales team. The image they present is very important.

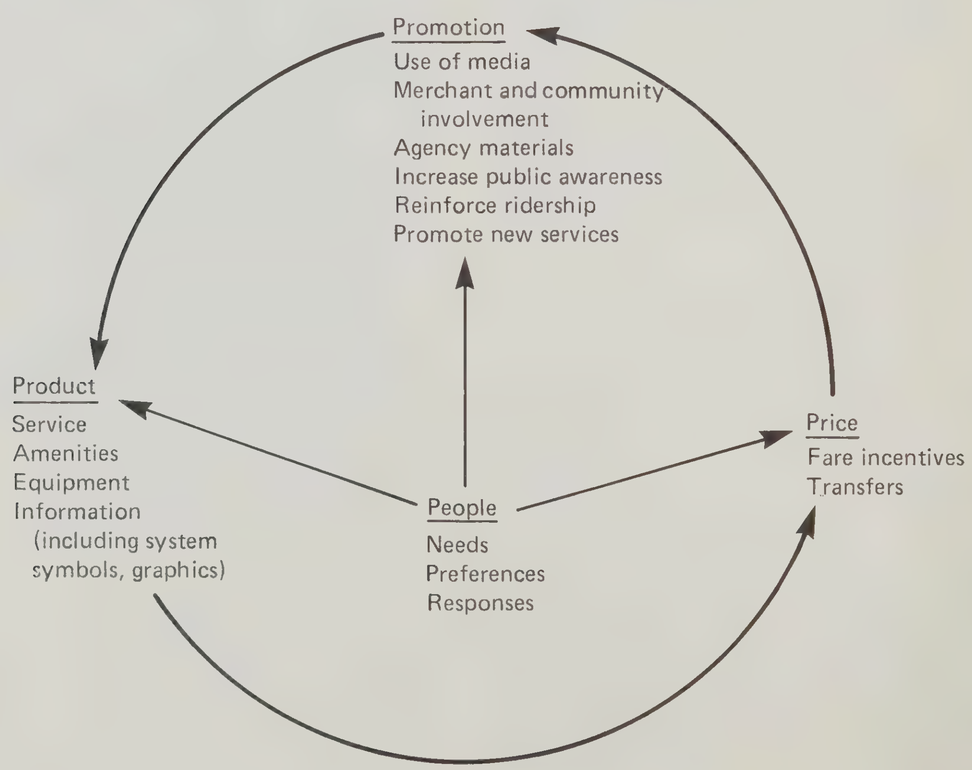
Public transit can also be promoted through the following media:

- newspapers, radio, TV ads,
- newsletters,
- press releases,
- displays,
- radio and TV talk shows,
- school visits,
- community clubs,
- Welcome Wagon.

Customer Service — The fourth component, customer service, is an important aspect of the marketing function. Customer service involves di-

Figure 3.6

Transit Marketing Cycle



rect contact with the public in an effort to make them aware of the service provided and how to use it. It is essential that the public have a means by which to obtain information relating to the transit system. Customer service should be capable of providing the following:

- route maps and timetables for existing service;
- special brochures and schedules for new-service introduction;
- bus-stop locations;
- fare structure;
- telephone information services;
- answers to complaints and suggestions.

3.8 Vehicle Operating and Maintenance Improvements

This section provides a generalized discussion of overall bus fuel consumption and those factors which have a direct impact on vehicular fuel consumption. Overall energy consumption will vary depending upon the type of vehicle and of service. Differences of 10% were noted in energy-efficiency estimates between urban-bus operations managed by the Toronto Transit Commission and commuter-bus operations under the Toronto Area Transit Operating Authority. As noted in Table 3.4, energy intensity decreases significantly from a CBD (Central Business District) collection/distribution operation to a line-haul service, largely as a function of speed and stop-frequency.

Speed Relationships — Relationships developed by the National Academy of Science *(National Cooperative Highway Research Program Report #111)* found that a constant speed of 50 km/h is the most energy-efficient for both gasoline- and diesel-powered vehicles. As speeds either increase or decrease, energy consumption

Table 3.4

Fuel Consumption by Rubber-Tire Transit Vehicles Under Various Operating Conditions

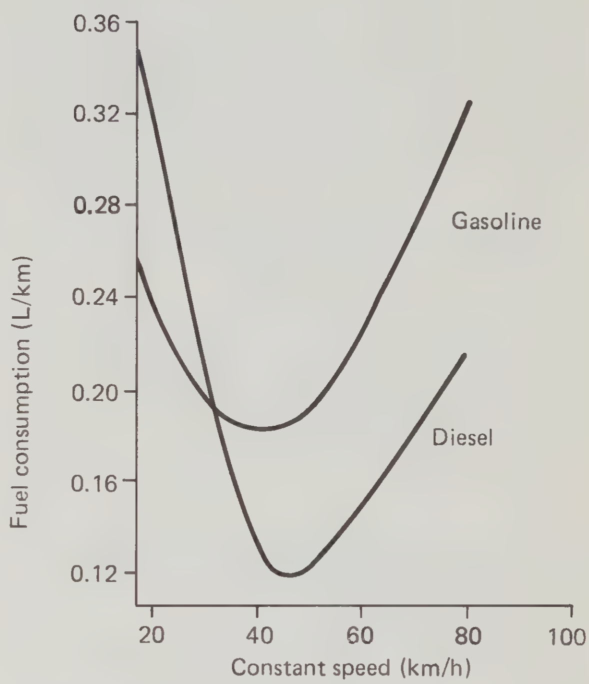
Type of trip	Average speed (km/h)	Fuel consumption (L/veh.-km)*	Intensity (MJ/veh.-km)*
Collecting – distributing			
CBD	16	0.59	22.8
Residential	24	0.45	17.4
Line haul			
Surface arterial	40	0.39	15.1
Exclusive busway	72	0.29	11.2

Source: *Method for Predicting Energy Impacts.* U.S. DOT, Transportation Systems Centre; 1978.

*veh.-km, vehicle kilometres; MJ, megajoules.

Figure 3.7

Bus Transit Fuel Consumption at Constant Speeds



Source: NCHRP 111 and Caltrans report.

increases dramatically (Figure 3.7). Generally, diesel-powered buses report lower fuel consumption than gasoline-powered ones. It should be noted that Figure 3.7 is based on ideal operating conditions (i.e., level terrain, no stops, etc.) and that actual fuel-consumption rates will vary, depending on local operating conditions.

Loaded Weight — As noted in previous sections, increasing load factors has the effect of improving fuel efficiency on a per-passenger basis. On the other hand, increasing bus-transit loads also has the impact of increasing vehicle weight and, therefore, increasing the energy consumption on a per-vehicle basis. Even though this loaded weight causes an increase in vehicular consumption, increased ridership still results in decreased fuel consumption *per passenger-kilometre.*

Improved Maintenance — Improved maintenance of vehicles has been estimated to allow savings of up to 10% on fuel consumption. Although the cost of elaborate maintenance programs may exceed the dollar savings of fuel consumed, other benefits such as equipment reliability could offset this difference. Basic maintenance should include:

- regular checking of tire condition and pressure, wheel alignment, and bearings;
- performance of periodic engine tune-ups to maximize fuel efficiency;
- inspection of fuel equipment regularly to minimize fuel spillage.

Indoor vehicle storage is an accepted practice in almost all properties in Ontario. This practice not only allows for easier vehicle start-ups, but also provides an opportunity for buses to shed the tons of ice which gather on vehicle undercarriages in the winter.

Operator Techniques — Driving improvements also serve as a viable means of reducing fuel consumption. Drivers should:

- avoid excessive idling of buses or supervisory vehicles;
- avoid racing the engine and slipping the clutch to build up engine pressure;
- avoid jackrabbit starts and quick stops;
- avoid lugging the engine excessively.

3.9 Transit Maintenance And Storage Facilities

The maintenance and storage facility of any transit property is the nucleus of transit operations. All transit vehicles enter and leave service via these facilities. When planning and designing new construction or renovation, it is important to consider the following energy-conservation features:

- location to reduce deadheading and non-revenue kilometres
- energy-efficient wall and roof construction
- use of glass on southern exposures to reduce internal lighting requirements
- use of shaded glass, thermopane glass, and recessed windows to reduce heating and cooling requirements
- use of shielded glass on southern exposures to reduce air conditioning requirements
- use of solar heating for hot water
- use of heat pumps
- provision for future solar panels
- additional insulation in older buildings
- recycling of asphalt and other materials
- installation of polycarbonate doors to reduce lighting and heating requirements (these doors are also lightweight and require smaller motors to open and close them)
- use of doors that open and close faster
- insulation of garage doors
- use of clear plastic strip door curtains
- regular inspection and adjustment of overhead doors
- electric door openers in bus-storage area
- lighting designed for working conditions in each area
- replacement of existing lights with higher-efficiency bulbs (e.g., low-pressure sodium)
- reduced lighting in non-essential areas (e.g., storage area)
- replacement timers for outside lights with photoelectric cells
- regulations requiring lights to be turned off when not in use (e.g., lunch hour)
- separation of bus-storage, maintenance, and office areas to allow control of heating levels
- vacuum-cleaning systems that filter and recirculate air inside the building
- recirculating fans in maintenance and storage areas
- lower thermostat settings in maintenance and office areas in off-hours
- electric heat with time-clock control for off-peak hours
- timers on exhaust and air intakes
- infra-red heaters
- modification of heater units and exhaust fans from automatic to demand-actuated control
- heat-transfer systems between work and storage areas
- heating and ventilation systems programmed to reduce heat also during door open-time
- conversion to more efficient fuel for heating (in Ontario electrical or natural gas heating is often more efficient than oil)

3.10 Alternative Fuels

At the present time, transit vehicles in the province operate on either gasoline, diesel fuel, or electricity. All standard buses — 9.2 m (30′), 10.7 m (35′), 12.2 m (40′) — operate on diesel fuel, while most of the smaller buses (15-20 passenger) and most school-type vehicles operate on gasoline. In Toronto and Hamilton, a portion of the transit service operates on electrical energy (subway, streetcars, and trolley buses).

Diesel Fuel — Although not regarded as an "alternative" fuel, diesel fuel has generally gained ready acceptance in preference to gasoline. Diesel fuel is promoted because diesel engines are more energy-efficient and diesel fuel contains a higher energy content. Most standard transit vehicles operate on diesel fuel.

Propane — Propane is also rapidly gaining acceptance as a viable alternative to gasoline. The Government of Ontario is promoting the use of propane through the *Drive Propane* demonstration. Ontario has provided tax incentives for all alternative transportation fuels.

Propane stock exceeds present demand. The amount exported from the Sarnia region alone could replace approximately 10% of the gasoline consumption in Ontario. Propane is both a component of natural gas at the well and a by-product at the refinery. Currently, 80% of our propane supply comes from natural gas and 20% is refinery-related.

Engine conversion necessary for propane use requires:

- pressurized fuel tank (690-1380 kPa/m^2; 100-200 lbs/sq. in.);
- special carburetion unit for vaporized fuel and air.

Conversions can be retrofitted to in-use vehicles through a propane supply company or through independent workshops. Propane is a suitable fuel for all vehicles currently using gasoline engines, including light and medium vans and trucks up to the range of 7.5 t to 11 t (20 000-30 000 lbs.) G.V.W. Diesel power becomes an increasingly stronger competitor in heavier vehicles. To assure best performance, the engine should be wholly converted to propane, rather than adjusted for dual operation. It is often found to be economical to operate a fleet from some central fuelling point which can be leased from and filled regularly by a propane supply company.

The energy content of propane (as a liquid) is only about 75% that of gasoline. Nevertheless, with the road-tax exemption (as of the April, 1980, Ontario Budget), propane is about 15% cheaper per VKT than unleaded gasoline. Factory-converted vehicles running exclusively on propane are also exempted from the 7% provincial sales tax. These cost factors make propane a very competitive fuel for fleet operators.

In addition to cost advantages, many users have also reported longer engine life and lower maintenance costs. Finally, fuel theft is very difficult, as liquid propane cannot be transferred to another pressurized container without a special pump. Chapter 6 discusses the advantages and disadvantages of propane as a substitute fuel.

An illustration of the potential applicability of propane to transit vehicles is found in Pickering, Ontario. The Town of Pickering Transit System has investigated the feasibility of installing propane on its *Thomas Mighty Mite Dial-a-Ride* buses (20-passenger). The results of this analysis were as follows:

Comparison parameter	Gasoline	Propane
Consumption rate (L/100 km)	23.58	26.18
Price (¢/L)	23.74	17.14
Operating cost (¢/km)	5.65	4.47
Annual distance traveled (km/bus)	72 450	72 450
Annual fuel cost ($/bus)	4095.00	3240.00
Annual saving ($/bus)		855.00
Additional savings ($/2-year period)		
Spark plug life extended 25%		20.00
Oil change, filters extended 200–500%		180.00
Engine life doubled*		1000.00

*Engine life is currently estimated to be 160 000 km using gasoline.

The estimated cost for conversion of the buses is $1652.65 for a 200-L tank and $1563.65 for a 150-L tank. The yearly rental for a 6800-L metred refueling facility is $882.00. Additional savings may be possible if the conversion is done by trained inhouse mechanics.

Transit Electrification — Electrified transit vehicles are currently in operation in Toronto, Hamilton, and other municipalities in Canada and around the world. The technology has been proven, and in many cases, trolley-bus infrastructure is still in place.

The major deterrent to a trolley-bus system is the high capital cost associated with the vehicle propulsion and the overhead wiring systems. In 1980, electrical energy costs were 10% lower than diesel fuel costs, but this saving was offset by higher maintenance costs associated with the trolley-bus power-distribution system. The Ontario Ministry of Transportation and Communications is currently reviewing the operating-costs differential of trolley buses vs diesel buses.

3.11 Land-Use Policy

Land-use planning is one element which can be used to influence transportation travel demand. This topic is discussed in Chapter 5, Travel Demand Management. However, a few comments are included here because of its importance to transit planning.

Land use is the key to transportation demand and, therefore, transportation energy consumption. Land-use patterns and intensities establish the

spatial relationships which determine the level of transportation demand. Generally, the greater the concentration of activities, the greater the opportunity to provide fuel-efficient transportation services such as transit operations and van pooling.

At the community level, higher density and mixed zoning can potentially reduce travel distances and make transit use more feasible by juxtaposing home and working places, and by bringing major traffic generators closer together. Intensifying land use along transportation corridors can encourage the use of public transit and give people a choice of travel modes.

Specific energy-conservation measures include:

- provision of residential densities that can support transit in all parts of the region;
- concentration of new urban development along major transit corridors, and around suburban centres;
- increasing multi-family residential construction throughout the urban area;
- improvement of the balance between people and jobs in all parts of the metropolitan area;
- increasing the mix and integration of land-use;
- provision of closer residential developments on smaller lots, and in locations where houses can be served by public transport;
- encouragement of the filling in of vacant parcels within the central city and its surrounding suburbs, especially with uses which enhance functional integration;
- encouragement of mixed-use buildings where large office, shopping, and residential complexes are combined into a single structure;
- planning of subdivisions and street layouts to improve transit vehicle circulation;
- provision of pedestrian walkways.

Consideration of public transit service must begin at the earliest stages of urban and land-use planning. For example, residential subdivision design has evolved toward the accepted practice of isolating homes by providing cul-de-sacs, circular internal streets, and other similar designs. Unfortunately, many of these have an adverse impact on the ability to provide efficient transit routings with easy pedestrian access.

Route planning involves difficult compromises between direct routing and pedestrian access. Because transit routing on arterial streets may be far removed from residential areas, it is important to provide pedestrian walkways. Similarly, subdivision street patterns which make use of indirect street systems as a means of reducing through-automobile movements should be redesigned to consider public-transit movements.

As noted above, clustering of activities, such as work, shopping, recreation, or socializing allows for the focus of transit trips. In all cases where physical conditions permit, transit routes should be as direct as possible and located to provide adequate service to the public without unnecessary duplication.

4 Energy-Analysis Methods

This section presents approaches for analyzing the effectiveness of transit energy-conservation measures.

For discussion of methods for analyzing the energy impacts of a broad range of transportation improvements, see Chapter 10.

4.1 Analytical Concepts

Three concepts are important in the analysis of energy consumption in transportation:

- direct and indirect energy consumption
- energy effectiveness
- modal composition of trips

Direct and Indirect Energy Consumption — Energy consumption may be classified as either direct or indirect. Direct energy is defined as that used to propel a vehicle and to support vehicle-related auxiliaries (e.g., gasoline). Indirect energy is that which is consumed during manufacture of materials, construction of infrastructure (e.g., highways or guideways), and maintenance activities. Indirect energy represents an investment in facilities and vehicles which may, in fact, reduce annual direct consumption in the future.

A "build" decision would be justified when the annual direct-energy savings of a project outweigh the sum of annual indirect-energy maintenance costs and the annualized indirect-energy construction cost.

It is also important to note that the current transportation infrastructure represents a "sunk" investment, the use of which should be optimized from the point of view of annual direct expenditure (i.e., net benefit).

Energy Effectiveness — The basic objectives of the transportation system relate to the movement of people. Therefore, the analysis of transportation energy effectiveness must also relate to the energy expended to transport a person from where he is (origin) to where he wants to go (destination).

Energy effectiveness may be analyzed either by energy efficiency or energy intensity. Energy efficiency is a measure of the amount of product resulting from an amount of energy consumed; for example, energy efficiency would be measured in terms of kilometres of automobile travel per litre of gasoline. Energy intensity is the inverse of energy efficiency. They are each expressed as follows:

$$\textit{energy efficiency} = \frac{\textit{distance}}{\textit{energy consumed}} \text{ (km/L)}$$

$$\textit{energy intensity} = \frac{\textit{energy consumed}}{\textit{distance}} \text{ (L/km)}$$

For consistency, energy consumption should be expressed in terms of joules (1 BTU [British Thermal Unit] = 1055 J [joules]). Because volumes of energy content are expressed in fairly large terms, megajoules (1 MJ = 1 million joules) and gigajoules (1 GJ = 1 billion or 1000 million joules) are used. Table 3.5 summarizes the modal energy intensity calculations developed as part of the *Metropolitan Toronto Area Transportation Energy Study (MTATES)*. It is important to differentiate between indirect and direct energy consumption, and between energy consumed per vehicle-kilometre, and energy consumed per seat-kilometre and passenger-kilometre.

The energy intensities per vehicle-kilometre and per seat-kilometre are generally transferable to other communities. However, the energy intensities per person-kilometre (i.e.,"crush" intensities) should reflect specific local conditions of loading and peak-hour traffic duration.

Rates of consumption on a per-seat-kilometre or per-passenger-kilometre basis give a clear picture of the person-moving efficiencies of a mode. The results illustrated in Table 3.5 represent the typical energy efficiency that could be achieved by various modes of transportation. On a per-vehicle-kilometre basis, the automobile represents the most efficient transportation mode. However, considering the larger loading capacities of public-transportation vehicles under maximum seating conditions, subways, trolley coaches, and streetcars offer the most energy-efficient modes of travel.

Relating these numbers in another manner, the "break even" passenger loadings were also determined in the MTATES Study. These values, shown

Table 3.5

Total Energy Intensity by Mode

Mode	Energy consumption (MJ/veh.-km) Indirect	Direct	Total	Energy intensity (MJ/seat-km)* Direct	Total
Automobile					
Freeway	1.37†	6.00‡	7.37	1.20	1.47‡
Arterial	1.53	6.20	7.73	1.24	1.55
Two-lane	1.58	6.30	7.88	1.26	1.58
Van					
Freeway	1.37	7.52	8.89	0.63	0.74
Arterial	1.53	7.52	9.05	0.63	0.75
Two-lane	1.58	7.52	9.10	0.63	0.76
Diesel urban bus	1.57	20.10	21.67	0.50	0.54 (0.22)§
Trolley coach	1.50	9.00	10.50	0.23	0.26 (0.11)
Subway	22.64	9.60	32.24	0.13	0.42 (0.10)
Streetcar	10.78	11.52	22.30	0.22	0.43 (0.17)
Commuter rail	14.15	91.86	106.01	0.57	0.66 (0.33)

SOURCE: Metropolitan Toronto Area Transportation Energy Study. 1981.

* Based on the following numbers of seats per vehicle: automobile, 5; van, 12; diesel urban bus and trolley coach, 40 (100 crush); subway, 76 (320 crush); streetcar, 52 (130 crush); commuter rail, 160 (320 crush).

† Assumes average life for automobile is 100 000 km.

‡ Assumes 17.2 L/100 km = 6.0 MJ/veh.-km. CAFE (1985) standard, 27.5 miles/U.S. gallon = 3.00 MJ/veh.-km (i.e. 0.87 MJ/seat-km total).

§ Figures in parentheses are energy intensity in MJ/passenger-km for modes where crush data apply.

in Table 3.6, provide a general guide for various communities. As shown, a diesel bus would have to carry only approximately 14 passengers to be as efficient as the theoretical loadings for the average automobile. Considering improved automotive efficiency as represented by the Corporate Automotive Fuel Efficiency (CAFE) Standards, equivalent transit loadings would have to increase to 23 passengers per bus. It is important to operate transit vehicles in such a manner that they can achieve greater than the equivalent passenger loadings shown in Table 3.6.

In the case of some public transit energy-conservation measures, it may be necessary to consider only a small segment of the total system or route. In these cases, it is essential that deadhead travel between the route and the transit storage and maintenance facility, and the empty backhaul on other route segments be taken into consideration in the overall analysis.

Table 3.6

Equivalent Passenger Loadings

Comparison mode	Design efficiency mode* Automobile Present	CAFE 1985	Van	Diesel bus	Trolley coach	Subway	Streetcar	Commuter rail
Automobile	—	—	n.p.†	n.p.	n.p.	n.p.	n.p.	n.p.
Van	6	(10)	—	n.p.	n.p.	n.p.	n.p.	14
Diesel bus	14	23	29	—	83	52	50	33
Trolley coach	7	11	14	19	—	25	24	16
Subway	21	35	43	60	124	—	75	49
Streetcar	14	24	30	41	86	53	—	34
Commuter rail	68	114	141	196	n.p.	252	247	—

SOURCE: Wilbur Smith and Associates. *Metropolitan Toronto Transportation Energy Study*. Prepared for Metropolitan Toronto Planning Department; March 1981.

* Direct and indirect energy. For example, to compare a vanpool operating at design efficiency, a diesel bus would have to have a continuous average load of 29 persons, a trolley coach 14, subway 43, etc., per car. Capacity on transit systems does not include crush loading.

† n.p., not possible

Modal Composition of Trips — Comparisons of energy consumption generally focus on the primary carrying mode, for example, automobile versus subway. However, each trip — especially those using public transit — may involve two or more vehicular modes. A comprehensive analysis of energy intensity must account for energy consumed from trip origin to trip destination.

A typical trip will involve an access mode, a line-haul mode, and an egress mode. Total energy intensity (MJ/km) can be determined by adding the energy consumed by each mode and dividing by the total travel distance. This accounts for both circuitous routing of each line-haul mode and of the access/egress components of the trip, and for the lower energy efficiency of access/egress modes.

Use of automobile or bus only may gain advantage because travel distance more nearly approaches straight-line distance. Similarly, when origins and destinations are closely clustered near a direct rapid-transit line, circuity will be minimized. Conversely, when access and egress distances are large in comparison to line-haul distance, the potential energy benefits of rapid-transit usage are minimized.

4.2 Energy-Analysis Procedure

The energy-evaluation methodology contains 6 basic steps, as outlined below. Depending on the conservation measure to be evaluated, not all the steps will be necessary.

Step 1:

Define Affected Population Group and Impact Type

The first step in evaluating an energy conservation measure is to identify which area of the transportation system will be affected. The general areas most likely to be affected are listed below:

- automobile — single occupant, car pool
- public transit — existing riders, new riders, extra buses, etc.
- type of trip — commuter, shopping, school, etc.
- number of trips — increase, decrease, no change
- time of day — peak hours, midday, evening, weekend
- geographical area — downtown, residential, industrial
- modal shift — from auto, car pool, bicycle, foot, etc.
- vehicle operations — vehicle efficiency, traffic flow, speed, etc.
- negative impacts — increased vehicle congestion, etc.

Step 2:

Choose Applicable Measure of Effectiveness

When an energy-conservation measure is implemented, a number of changes will occur in the transportation system. Each of these changes can be measured and will have a direct impact on total energy consumption. The measures of effectiveness listed below are designed to record the changes in key (measurable) variables.

- changes in vehicle efficiency (km/L) or intensity (L/100 km)
- changes in load factors (passenger-km/vehicle-km)
- changes in modal split and ridership
- changes in auto trips and VKT

The total benefit in terms of reduced energy consumption will be the sum of the above changes. Depending on the conservation strategy, some of the above changes may not be applicable. Table 3.7 presents a summary of the major energy implications and the associated evaluation equations with examples.

Step 3:

Estimate "Before" and "After" Conditions

In order to evaluate the effectiveness of each conservation measure, it is essential to estimate or calculate energy consumption before implementation and compare this data with the energy consumption expected once the conservation measure is fully implemented. The basic set of data required to estimate the "before" and "after" conditions is listed below.

- trip length
- number of trips
- modal share
- automobile ridership
- transit ridership
- vehicle fuel-consumption rates

The above data for the "before" conditions may be obtained from readily available information or through special surveys conducted as part of the market research. Depending on the specific conservation measure under consideration, some or all of the above information will be required for both the "before" and "after" conditions. In some cases, it may not be necessary to estimate both the "before" and "after" conditions if the particular conservation measure can be easily related to an actual change in conditions.

The calculations or estimates should be as accurate as possible, keeping in mind the purpose of the analysis. It is most important that the assump-

tions related to the changes be well-developed and reasonable and that the degree of change, its cause, and its possible evolution over time be fully understood.

Step 4:

Calculate Energy Consumption

Energy consumption is calculated by applying the data collected in *Step 3* to each applicable measure of effectiveness identified in *Step 2*. In the case of some public-transit conservation measures, the automobile energy is calculated separately from the transit-vehicle energy and then the two are combined to arrive at the overall energy consumption. Example calculations are shown in Table 3.7.

Transit Energy — The direct energy consumption for transit vehicles is the energy required to propel the vehicle; it is usually measured in litres per 100 kilometres (L/100 km). Typical fuel consumption rates are generally available from vehicle records; this figure can be applied to the total vehicle-kilometres operated, including non-revenue kilometres, to arrive at the total overall consumption.

The indirect energy consumption for transit vehicles includes the energy required to manufacture and maintain any additional buses, or fixed facilities required to implement the conservation measures. This energy measurement is expressed in megajoules per vehicle-kilometre travelled (MJ/VKT). The appropriate energy value can be obtained from Table 3.5 and applied to the total vehicle-kilometres travelled.

Automobile Energy — The following steps are only necessary if the energy-conservation strategy is expected to produce a modal shift from the automobile to public transit for all or part of the trip. In this portion of the analysis, it is usually easier to estimate the net change in automobile energy.

- Estimate the number of passengers that will shift from the automobile to public transit.
- Estimate the net reduction in automobile trips (new transit passengers ÷ average auto occupancy).
- Estimate the net reduction in automobile-kilometres (number of auto trips eliminated × average automobile trip length).
- Estimate the net reduction in direct automobile energy consumption (reduced auto-km × average automobile fuel consumption [L/100 km]).
- Estimate the net reduction in indirect automobile energy consumption, considering:
  - facility construction and manufacture,
  - facility operations and maintenance,
  - vehicle manufacture and maintenance.

It should be noted that the construction and manufacturing energy of existing highway and transit facilities should be considered as a "sunk" investment and therefore excluded from the analysis. The question of including or excluding automobile manufacturing energy is debatable. Generally speaking, the public is not likely to dispose of a second automobile because of a small change in their overall travel habits. However, major shifts to car pools and public transit can reduce the need for the second or third car in some households. Ultimately, this will result in energy savings.

Indirect energy is expressed in megajoules per vehicle-kilometre. The appropriate energy values can be obtained from Table 3.5 and applied to the net change in vehicle-kilometres travelled.

Step 5:

Net Change in Energy Consumption

To calculate the net change in energy consumption, it is necessary to add up all the energy-consumption figures for the "after" condition and then subtract the total energy figures for the "before" condition. In some cases, it may only be necessary to add up all the changes in energy consumption, such as the increase or decrease in transit energy plus the increase or decrease in automobile energy. This net change in energy consumption will include both direct (L, kWh) and indirect (MJ) energy components. To obtain a picture of the overall change in energy consumption, the direct energy component can be converted into megajoules (using the factors in Table 3.7 for conversion of litres into megajoules), and added to the indirect energy component.

Optimally, the net change will show an overall reduction. However, there may be some cases where the results will indicate an increase in energy consumption. This may be due to either the direct-energy component, the indirect-energy component, or both. It should be noted that the direct-energy component is the most important in that it relates directly, in most cases, to crude-oil consumption.

Step 6:

Cost/Benefit Analysis

Once the energy analysis is complete, it is necessary to compare the total net energy benefit, if any, to the total cost of the conservation measure. This procedure will allow the transit manager to evaluate a wide range of conservation measures and to establish a priority listing of the measures which are the most cost-effective. The major steps in the cost/benefit analysis are outlined below.

Table 3.7

Evaluating Direct Energy Savings

Change in automobile travel (modal shift to transit)

$$\Delta ADE = \frac{(TR_b - TR_a) \times FAP \times ATL}{AO} \times AFC$$

Annual transit ridership before (TR_b)	100 000
Annual transit ridership after (TR_a)	150 000
Former automobile passengers (FAP)	80%
Automobile trip length (ATL)	2 km
Automobile fuel consumption rate (AFC)	15 L gasoline/100 km
Automobile occupancy (AO)	1.5

Change in auto direct energy, $\Delta ADE = \frac{(100\,000 - 150\,000 \times 0.8 \times 2)}{1.5} \times \frac{15}{100}$

$= -8000$

Therefore, the change in auto direct energy is a decrease (a plus sign would denote an increase) of 8000 L of gasoline per year or 8000 × 34.66 MJ/L* = 277 280 MJ per year.

Change in bus travel

$$\Delta BDE = (BT_a - BT_b) \times BFC$$

Annual bus travel before (BT_b)	50 000 km
Annual bus travel after (BT_a)	40 000 km
Bus fuel consumption rate (BFC)	50 L diesel/100 km

Change in bus direct energy, $\Delta BDE = (40\,000 - 50\,000) \times \frac{50}{100}$

$= -5000$

Therefore, the change in bus direct energy is a decrease of 5000 L of diesel fuel per year or 5000 × 38.68 MJ/L* = 193 400 MJ per year.

Change in bus fuel efficiency

$$\Delta BDE = BT \times (BFC_a - BFC_b)$$

Annual bus travel (BT)	100 000 km
Bus fuel consumption rate before (BFC_b)	50 L diesel/100 km
Bus fuel consumption rate after (BFC_a)	45 L diesel/100 km

Change in bus direct energy, $\Delta BDE = 100\,000 \times \frac{45}{100} - \frac{50}{100}$

$= -5000$

Therefore, the change in bus direct energy is a decrease of 5000 L of diesel fuel per year or 500 × 38.68 MJ/L* = 193 400 MJ per year.

Table 3.7 (continued)

Conversion of buses to alternate fuel

$$\Delta BDE = BT \times (BEC_a - BEC_b)$$

Annual bus travel (BT)	50 000 km
Bus energy consumption before (BEC_b)	8.3 MJ/km* (24 L gasoline/100 km)
Bus energy consumption after (BEC_a)	6.7 MJ/km* (26 L propane/100 km)

Change in bus direct energy, $\Delta BDE = 50\,000 \times (6.7 - 8.3)$

$= -80\,000$

Therefore, the change in bus direct energy is a decrease of 80 000 MJ per year or an increase of 13 000 L of propane per year to save 12 000 L of gasoline per year.

Conversion of facility heating to alternate fuel

$$\Delta FDE = FDE_a - FDE_b$$

Annual facility direct energy before (FDE_b)	17.7×10^6 MJ/year* (454 000 L oil/year)
Annual facility direct energy after (FDE_a)	10.6×10^6 MJ/year* (285 000 m^3 natural gas/year)

Change in facility direct energy, $\Delta FDE = 10.6 \times 10^6 - 17.7 \times 10^6$

$= -7.1 \times 10^6$

Therefore, the change in facility direct energy (heating) is a decrease of 7.1×10^6 MJ per year.

*Conversion factors for the energy forms used in this example are: crude oil, 38.51 MJ/L; diesel fuel, 38.68 MJ/L; motor gasoline, 34.66 MJ/L; electricity, 3.60 MJ/kWh; propane, 25.6 MJ/L; natural gas, 37.23 MJ/m^3; heating oil, 38.68 MJ/L (*Ontario Energy Review*, 2nd ed. Ontario Ministry of Energy; March 1981. 49 pp.).

The first step involves the estimation of all costs associated with the implementation of the conservation measure. These costs may include the capital costs of buses, equipment, and infrastructure; the implementation costs; and the operating and maintenance costs. Each of the cost components should be converted to annualized values and added to arrive at a total annual cost. In some cases, it will be necessary to deduct the additional annual revenue generated by new transit passengers.

The second step is to calculate the cost/benefit ratio by dividing the total annual net cost by the total annual net energy savings. This ratio can be expressed either in terms of dollars per megajoule or dollars per litre of fuel saved. Gasoline and diesel fuel can be considered separately, although the indirect energy component should still be part of the analysis.

It is also possible to estimate the net financial impact of the conservation measure on the community as a whole. This involves subtracting the annual cost of the energy saved by the community from the net annual cost of the conservation measure. For some measures, there may not be a financial return until sometime in the future, depending on the relative cost of petroleum fuels compared to the annual costs of the conservation measure.

Once the cost/benefit analysis is complete, those measures which are the most cost-effective can be implemented. It is desirable for a municipality to consider an overall conservation program which would include transit measures as well as other transportation and municipal energy-conservation measures.

Ontario

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Energy
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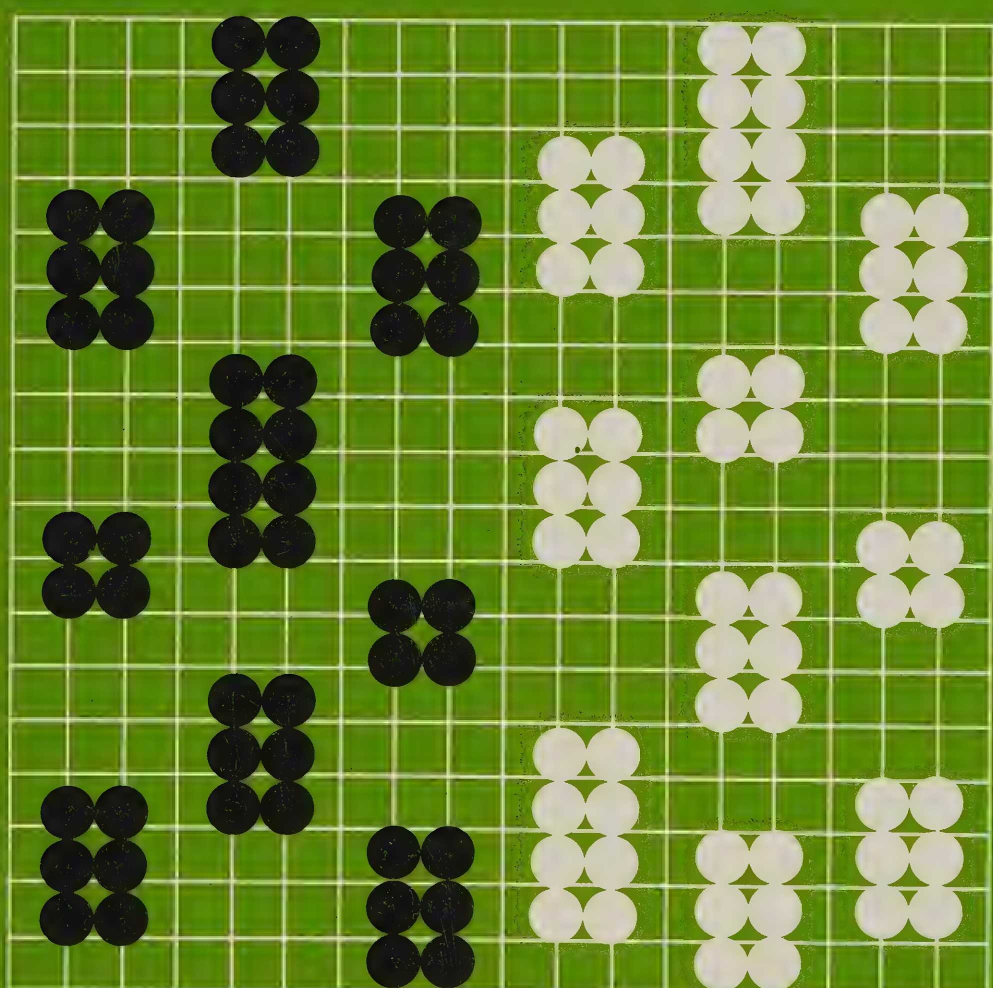
Transportation Energy Analysis Manual

4:
Ridesharing



The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM
Transportation Energy Analysis Manual

4:
Ridesharing

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Preface

The purpose of the **Transportation Energy Analysis Manual (TEAM)** is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within their municipality. The Manual is organized into ten chapters, which outline the principal technical ways to conserve energy through transportation improvements.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is the crucial public-sector level because these decision-makers deal with the day-to-day activities of the thousands of citizens residing within their municipalities. Energy conservation is an on-going, everyday affair, and the municipality is directly involved.

The **Transportation Energy Analysis Manual** will consist of chapters on the subject areas listed below. The Manual is being produced chapter by chapter as each is completed. These in turn will be updated as considered necessary.

Executive Summary
1. Program Overview
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Energy Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Program Management
10. Energy Analysis Methods

This chapter, **Ridesharing**, focuses on and highlights the various approaches and types of service available to those interested in ridesharing to conserve energy.

Additional information on the Manual or on any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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1 Overview

1.1 Introduction

This chapter deals with ridesharing, which is the use of a vehicle by more than one person. Public transit is, of course, the major form of common vehicle usage. It is not, however, commonly referred to as ridesharing. (Transit is discussed in Chapter 3 of the Manual.) Individual ridesharing measures and their effectiveness in conserving energy are discussed here, together with strategies by which municipalities can institute them.

One of the cheapest and most effective methods of saving energy is to increase the occupancy of vehicles on the road. Two neighbours working in the same building can cut their work-trip energy consumption in half by sharing a ride. Ridesharing, which includes carpooling, vanpooling, and paratransit (see Section 1.5), offers the potential to reduce energy consumption significantly at modest implementation costs. Ridesharing is a flexible means of achieving increases in vehicle occupancy or ridership.

1.2 Ridesharing Programs: Approaches and Types of Service

Municipalities can institute ridesharing programs directed at their own employees or at the general public; they can also promote and assist in ridesharing programs implemented by private firms. These programs can be effectively coordinated with a wide range of highway, parking, or governmental incentive programs which will further encourage ridesharing.

Ridesharing programs can be classified by type of vehicle and service concept:

- carpools using private automobiles;
- vanpools using specially-equipped 12-passenger vehicles;
- paratransit operations such as contract van service;
- shared-ride taxi;
- *dial-a-ride*;
- subscription bus;
- reserved-seat express bus.

Ridesharing programs can also be categorized by the program approach: an employer-based program is directed at a single group such as the employees of a certain firm or group of firms; an area-wide program is directed at the broader market of all individuals in a given area.

Employer-based programs are directed at either single employers or concentrations of employers. The greatest opportunity for ridesharing occurs when people work similar hours in adjacent locations. Because of this, employer-based programs have been extremely successful. Employer-based programs are organized either by the employer or by an outside agency (usually called a third-party agency). In the case of a carpool program, the company would promote the concept, supply ride-matching information to employees, and set aside preferential parking spaces for carpoolers. With a vanpool program, the company would promote the concept, acquire and insure the vans, and collect fares to recover costs associated with the vans. It would also provide administration without charge, and set aside priority parking for the vans.

Third-party agencies can be very effective in providing ridesharing services, using an employment centre as a base destination.

Area-wide ridesharing programs are directed at a broad segment of the general public, providing opportunities to form or join a carpool or vanpool. Area-wide programs include development and implementation of media articles and other publicity, explaining advantages and encouraging involvement in ridesharing. Comprehensive area-wide programs involve the establishment of regional coordinators, matching, and other similar administrative services.

1.3 Carpooling

1.3.1 Organization

Carpooling is the most flexible, as well as the most generally applicable, type of ridesharing service concept. This approach makes use of privately-owned automobiles and members may either: rotate driving on a daily, weekly, or monthly basis; pay a fee to a designated driver on a weekly or monthly basis; or, in some cases, purchase a separate vehicle to be used solely for the commuting task. While carpooling is generally di-

rected at work trips, school trips and travel for team sports may also be ideally suited to carpooling efforts.

A prime concern in establishing carpooling arrangements is automobile insurance. Increasing liability insurance coverage may be a sound idea because of the increased risk of personal involvement in accidents. If a carpool driver accepts payment from passengers, his insurance must have auto endorsement SEF6A, "Permission to Carry Passengers for Compensation Endorsement." This endorsement will cost $10.00 to $25.00 per year and could be considered part of the carpooling cost.

For regular carpool passengers, on the other hand, automobile insurance rates may drop as much as 23% because their automobiles are no longer used for commuting. Even using a car for a regular turn in a carpool may involve an insurance-rate decrease because of the lower total annual commuting distance involved. A local insurance agent should be consulted in any event.

The procedures for setting up a carpool or vanpool program are described in Section 2.4.

1.3.2 Effectiveness

The cost-effectiveness of carpooling programs is outstanding for the individual and the community. Moving from single-occupant vehicles to two persons per vehicle will reduce cost and energy consumption by 50%. Moving to a four-person carpool can increase savings to 75%. In addition to cost and energy considerations, there is also potential for reduced driving strain and the increased personal flexibility brought about by having additional automobiles available for the journey-to-work trip.

There is an upper limit to the potential for carpooling because of the use of the vehicle at work and the limited number of reasonable ride matches that actually exist. However, the greatest obstacle at present appears to be the lack of programs to organize carpools.

1.4 Vanpooling

1.4.1 Organization

Vanpooling is a further extension of the carpooling concept and involves the utilization of a 12-passenger vehicle. In general, whether the van is acquired privately or with employer support, the passenger pays a monthly fare to cover all operating and capital costs. Vans may operate either from central meeting places or through door-to-door service. In terms of the organization of vanpools, there are four basic types:

- *private arrangement*, in which the van is owned and operated by one member of the pool as a business venture;
- *commuter association*, in which the van may be jointly owned/leased and operated by pool members as a joint venture;
- *employer-sponsored*, in which the van may be supplied by an employer to a commuting group of employees paying monthly or weekly charges;
- *third-party*, in which a van is supplied by a vanpool agency with an option to return the van with no penalty if the pool fails.

Two programs have been established in Ontario to assist municipalities, employers, and other groups in the organization and operation of vanpool programs.

The Ontario Government, through its *Share-A-Ride* program, is promoting the concept of vanpooling in both the public and the private sectors. It offers expert assistance in the development and implementation of vanpool operations. The major thrust of the program has been to encourage large employers to establish a vanpool program for their employees. If an organization or an individual is interested in setting up a vanpool, *Share-A-Ride* can be contacted at (416) 248-7296.

The Ontario Van Pool Organization, Ltd. (OVPO), provides services similar to those of a third party agency. OVPO is an affiliate of the Ontario Energy Corporation and reflects the Ontario Government's commitment to saving energy and reducing gasoline consumption. OVPO will make available to groups of 10-12 commuters a customized maxi-van, equipped with comfortable individual seats, carpeting, tinted glass, air conditioning, radio, and other features. The agency undertakes all financing and ownership arrangements for the vans, as well as insuring them and maintaining each one in top operating condition. It provides promotional and administrative support to groups in planning, organizing, and maintaining their vanpools. Interested groups are invited to call OVPO at (416) 965-8102.

The procedures for organizing a vanpool program are outlined in Section 2.4.

1.4.2 Issues and Constraints

Because vans offer greater seating capacity than private automobiles, their operation involves more legal issues and constraints. Some of the legal issues are:

- *Motor carrier regulations.* Vanpool vehicles do not require special licensing, provided the following conditions prevail:
  - seating capacity is 12 or less;
  - passengers pay for their transportation no more frequently than on a weekly basis;
  - a driver makes only one round trip per day;

– only one vanpool vehicle is operated by the owner or lessee.

Employer-sponsored vanpools are exempt from the last restriction if the majority of vanpoolers are company employees.

- *Vehicle registration.* A passenger van with 10 or more seats is registered as a commercial motor vehicle and classified as a bus (body type).
- *Driver licensing.* A Class *F* licence is required for drivers of vehicles with 10-24 seats. The licence requirements include a written examination and driving test, an eye test, and a medical examination.
- *Insurance.* Vanpool insurance should be available for between $450 and $650, based on $1 million third-party liability, standard accident benefits (no fault), collision ($250 deductible), and comprehensive ($50 deductible) coverage. The standard auto endorsement SEF6A, ("Permission to Carry Passengers for Compensation Endorsement") is essential. Some companies will be less willing to write a policy than others because of their limited experience in insuring vanpools in Ontario.

1.4.3 Effectiveness

Vanpools have the potential to reduce cost and energy consumption more than carpools because of their greater passenger-carrying capacity. They are particularly effective for long journeys where the line-haul distance is high compared to the extra distance incurred in picking up and dropping off passengers at the beginning or end of the trip.

Vanpooling is a significant energy conservation measure. By replacing as few as 12 cars, 29 000 litres of gas can be saved per year, assuming an average round trip of 80 km. The savings increase with the trip length.

Long-distance commuters have the most to gain from vanpooling. For example, a commuter who makes an 80 km round trip daily will spend $106/month for gasoline alone (assuming 15 L/100 km at 42¢/L). The cost of oil changes, maintenance, and tire replacement increases this cost to $156/month. This amount does not include the cost of the car, depreciation, insurance, or annual registration. For round trips longer than 60 km, vanpooling is cheaper than a 2-person carpool, and when comfort and convenience are considered, vanpooling is an attractive alternative to larger carpools.

The largest savings for vanpoolers can come from selling (or not having to buy) a second car. By no longer having to own and insure a second car, one can save more than $1500 per year.

1.5 Paratransit

1.5.1 Organization

Paratransit services have been defined as those forms of intra-urban passenger transportation which are available to the public, are distinct from conventional transit (scheduled bus) and can operate over the highway and street system. This overall definition includes: short-term rental cars; taxi, van, and jitney services; dial-a-ride services; carpools; and subscription bus services. Four broad service categories can be defined in paratransit services:

- integrated service with the conventional transit system, utilizing shared-ride taxis, vans, or small buses;
- pre-arranged subscription-bus ridesharing;
- service for special groups (handicapped, elderly, etc.);
- the sole service in small communities.

Integrated Service — The provision of fixed-route transit service in the low-density fringes of urban areas, particularly during the off-peak periods, is very energy-inefficient and expensive. It may be that paratransit can be used in these situations to provide transit service sooner than it would be economically feasible to provide a regular bus service. In this manner, transit use might be promoted before travel patterns of new residents are established and, in some cases, second cars purchased. As the demand grows and exceeds the capacity of paratransit, regular transit service can be introduced.

Supplementing transit with paratransit in the off-peak periods in low-density areas can save energy and money. These services tend to be more fuel-efficient and cost-effective than regular conventional transit because of the use of smaller vehicles and private operators. Typical characteristics of paratransit-type operations used to replace conventional transit are:

- low ridership,
- private contractor,
- smaller vehicles.

A contract van service may operate in the evenings, on Sundays, and on holidays, replacing the fixed-route bus system which runs in the daytime during the week. The vans may follow the same fixed routes as the buses, on the same schedule, perhaps providing a feeder service to a main-line bus route which runs downtown.

Consideration can also be given to replacing *dial-a-ride* buses with shared-ride taxis. The high cost of operating *dial-a-ride* as part of a municipal transit system with inadequate ridership levels has resulted in the elimination of a number of such operations. The benefit of a taxi-based demand-responsive system is that the dispatching cost

and the vehicle-operating costs can be shared over a wider number of users; i.e., the other taxi users as well.

Subscription Bus Service — A bus can be used for pre-arranged ridesharing in a manner similar to that of carpools and vanpools. Subscription buses leased on a subscription work-trip basis are a cost-effective and energy-efficient method of serving commuters. Charter arrangements in which employers pay for most or all of the cost of providing the service are particularly effective. The implementation and installation of this type of service requires much greater residential and employment concentration than that suitable for car- or vanpools.

Special Group Service — Paratransit service for special groups such as the handicapped has been introduced in many Ontario communities. These special services are more cost-effective and energy-efficient than adapting regular transit equipment to suit minority needs.

Small Communities — Small communities where population and potential transit ridership do not warrant transit service may benefit from paratransit service. This service, using vans or taxis, would be similar to the supplementary service described in the preceding paragraphs for the fringe areas of larger communities.

1.5.2 Issues and Constraints

There are a number of legal and institutional constraints which may have to be overcome in order to implement paratransit. These depend on local municipalities' bylaws, union agreements, and the type of paratransit proposed. Some of the issues are:

- *Union agreement*. The bus operators and mechanics in municipal transit systems are usually members of the Canadian Brotherhood of Railway, Transport, and General Workers. The collective agreement between the municipality and the union may prohibit the use of part-time workers, contracted service, or other forms of paratransit. The union local should be consulted in the development of any paratransit plan which will affect the union members, and urged to cooperate with the municipality in the promotion and improvement of service and the conservation of energy.
- *Public Vehicles Act*. The Public Vehicles Act is the act regulating the carrying of passengers for compensation from one municipality to another. Public vehicles require a licence from the Ontario Highway Transport Board. Exempt from the provisions of the act are motor vehicles operated solely within the corporate limits of one urban municipality, and taxis ("motor vehicles," as defined in The Highway Traffic Act, "having a seating capacity of not more than six persons, exclusive of the driver, hired for one specific trip for the transportation exclusively of one person or group of persons, one fare or charge only being collected or made for the trip."). Paratransit service entirely within one municipality or service using taxis would not require a public-vehicle licence or a hearing before the Ontario Highway Transport Board.
- *Ontario Municipal Act*. For trips which have both ends within the same municipality, the Ontario Municipal Act has granted municipalities the right to the exclusive franchise to operate local passenger-transportation services. This is usually exercised by the municipal transit commission or department. The transit department of a municipality should be involved in planning any proposed paratransit and should be in agreement with the proposals. Vanpools are suitable in areas not well served by transit, but may be a duplication of service and/or counterproductive to some extent in those areas well served by transit.
- *Taxi by-laws*. Most municipalities have a taxi by-law to license, regulate, and govern owners and drivers of cabs and other vehicles used for hire. Often administered through the office of the clerk, the by-law may prohibit shared-ride taxi service, and a number of minor points might require amendment if taxis are used in paratransit shared-ride taxi applications. These include regulations with regard to fares, cruising, hailing, etc.
- *Insurance*. Insurance carried by paratransit operators should usually be a minimum of $1 million for public liability and $2 million for passenger injury. Coverage should reflect the needs of the particular paratransit application.
- *Driver's licensing*. A Class *G* licence is required to operate vehicles which would carry up to 9 passengers. This is the basic driver's licence that most people obtain. A Class *F* licence is required to operate small buses or vans which hold 10 to 24 people, a Class *E* licence to operate a school-purpose bus of up to 24 passengers. (Class E licence holders are permitted to drive ordinary small buses or vans as well.) The Class F licence requires the driver to meet significantly higher standards of physical fitness, visual acuity, and mechanical knowledge than does the Class G licence. The applicant must pass a written test, a driving test, a vision test, and a medical examination. The applicant must take the driving test in a vehicle with 10 or more seats and must be familiar with the engine components and indicator dials.

1.5.3 Effectiveness

When passenger volumes are low, particularly in low-density areas in off- peak periods, paratransit

service with vans or taxis is more cost-effective than conventional bus service.

The cost per vehicle-hour of operating a van or taxi is approximately half that required to operate a bus. The cost will therefore be less than that for a bus on routes where fewer than three paratransit vehicles are sufficient to carry the passenger volume. This is often the case on suburban routes in the off-peak periods when very few passengers are carried. This reduced cost in low-volume situations derives from four factors:

- The small-sized vehicles have lower depreciation and maintenance costs.
- Converting small gasoline or diesel engines to propane operation can provide greater fuel and cost efficiency. Propane may be less suitable for large passenger buses but has been demonstrated to be very effective for vans.
- The use of part-time drivers without uniforms and with lower salaries and fringe benefits means reduced labour costs.
- The vehicles can be used for other purposes (such as school trips, charters, taxi service) when not used in transit service. This will spread the fixed costs, depreciation, etc., over a wider market. Paratransit service would operate primarily during the evening hours when, for example, vans and taxis are not busy taking adults to work or children to school. Of course, all such operations must be properly licensed and authorized by the appropriate authorities.

Fuel consumption of a conventional bus is more than double that of a van or taxi. When the maximum passenger load on a given route is lower than about 20 people (the capacity of two vans), energy can be saved by using paratransit instead of conventional buses. At higher passenger volumes, buses are more fuel-efficient.

2 Ridesharing Implementation Measures

2.1 Introduction

Municipalities can adopt a variety of ridesharing-based energy-conservation measures. The level of effort (and, therefore, the results) depend on the policy decisions and commitment of municipal authorities. Some steps that could be taken follow.

- Appoint a ridesharing coordinator for the municipality.
- Investigate the market for ridesharing in the municipality, analyze the existing situation, and monitor developments.
- Develop a ridesharing program for municipal employees.
- Promote and support employer-based ridesharing programs and help neighbouring employers to coordinate their efforts.
- Promote area-wide carpooling in the municipality, including neighbourhood ridesharing.
- Provide subscription bus service.
- Provide paratransit in fringe areas of the municipality.
- Institute parking incentives and related policies to encourage ridesharing.

These measures are discussed in the sections that follow, together with their objective, description, and effectiveness.

2.2 Appoint Ridesharing Coordinator

2.2.1 Objective

The objective of this measure is to appoint a municipal staff member to coordinate ridesharing efforts in the community. This person can act as a focus for ridesharing efforts and provide a central contact for information collection and dissemination.

2.2.2 Description

The ridesharing coordinator should be a member of the municipal transportation planning staff, or a staff member in the planning or engineering departments, if transportation is not identified separately. He can be an existing staff member with other duties in a smaller municipality, or the position can be created just for the purpose of coordinating ridesharing on a full-time basis. Adequate support and secretarial staff, as well as office space, should be assigned to the position.

The duties of the ridesharing coordinator would vary in scope depending on the municipal policy decisions as to which ridesharing measures are to be instituted. The ridesharing-program coordinator would be in charge of contacting and dealing with employers and others involved in ridesharing. He would act as a broker to match ridesharing supply and demand. The ridesharing coordinator could coordinate individual ridesharing efforts by establishing a comprehensive (and regularly updated) data bank, by developing and performing matching services, by managing the implementation of promotional and marketing programs, and by identifying potential markets for ridesharing.

2.2.3 Effectiveness

The appointment of a ridesharing coordinator is the first measure that should be undertaken in the municipality if any ridesharing measures are contemplated. The coordinator should be closely involved with other energy-conservation programs undertaken by the municipality (as outlined in this manual), such as the contingency energy-conservation plans for an energy emergency situation, high-occupancy-vehicle priority-treatment measures, and travel demand-management policies.

2.3 Investigate Ridesharing Market in Municipality

2.3.1 Objective

The objective of this measure is to investigate the existing ridesharing in the municipality, identify the potential market for additional ridesharing, and monitor developments in ridesharing as they occur, whether as a result of municipal, provincial, or employer programs.

2.3.2 Description

The municipality should develop and maintain a list of firms (employers) and number of employees by location. This is often done in con-

junction with transportation planning studies or it may be maintained by the Industrial Commissioner. It provides a basis for organizing potential employer-based ridesharing programs.

The ridesharing coordinator should contact the *Share-A-Ride* staff at the Ministry of Transportation and Communications and establish a liaison between Share-A-Ride, the municipal staff, major employers, and the public. The Share-A-Ride program has already contacted many large employers in Ontario through the provincial promotion program for ridesharing.

Additional surveys of employers should be conducted to determine the nature and scope of existing car- and vanpooling. This information is useful for transportation and traffic planning in the municipality, in addition to other ridesharing purposes. A household ridesharing survey could be enclosed in utility bills. The ridesharing coordinator should also review previous transportation studies in the municipality to obtain the general background of travel patterns and other relevant information. Ridesharing programs in other municipalities should also be studied in the planning process.

Current carpooling, vanpooling, and paratransit systems should be evaluated to assess the methods used, the results achieved, and the potential for coordination and improvement.

2.3.3 Effectiveness

This investigation will provide the basis for subsequent ridesharing programs. Problems can thus be identified and remedied in advance. It is anticipated that the resulting coordinated effort will be more effective than ad hoc ridesharing measures undertaken by individuals and firms.

2.4 Develop Ridesharing Program for Municipal Employees

2.4.1 Objective

The objective of this measure is to develop a suitable ridesharing program for municipal employees. Depending on the size and concentration of employment, this could be a carpool or vanpool program. In addition to the direct energy-conservation benefits, such a program shows municipal commitment, provides visibility to the concept, and gives the coordinator direct experience in program organization.

2.4.2 Description

A ridesharing program based on a major employment centre requires certain organizational and support activities. This section describes a ridesharing program for the municipal office which is also typical of any employer-based program.

Management Support — Municipal senior staff and politicians should make policy decisions on the level of support to be offered for the ridesharing program for municipal employees. Experience has shown that ridesharing programs achieve higher levels of success when management endorses the program and provides the resources to implement and maintain it. In addition, the probability of success is often increased by various incentives an employer can provide to vanpoolers and carpoolers, such as preferential parking and adjustments to working hours where necessary to promote the formation of pools. Employers can also support a ridesharing program through promotional efforts, using special brochures, posters, newsletters, and other available media to inform employees about the program.

For vanpools, the municipality can provide, without charge, the accounting and payroll functions necessary to handle operating costs and collection of passenger fares. Where municipalities have existing vehicle fleets, van maintenance may be provided at favourable rates. Similarly, it may be possible to obtain low-cost insurance coverage through the municipality's insurance policy. The municipality may provide greater financial support by absorbing interest costs incurred through purchase of the vans, or by providing free rides during the first few weeks of a vanpool's operation.

The method of van acquisition and ownership must be decided for vanpools. Municipally owned or leased vans can demonstrate a commitment to vanpooling that will instill confidence in the riders that the program will be properly operated and monitored. The municipality may be able to use the vans for business purposes during the day as well. This would lower van fares (the municipality could cover an appropriate portion of the operating and fixed costs) and is, therefore, desirable, provided that the business use does not interfere with operation of the vanpool. Insurance coverage should be consistent with municipal fleet policy.

Administration — The municipal-employee ridesharing program may be administered by the ridesharing coordinator, as discussed in the preceding section, or by another individual carpool coordinator or vanpool administrator working with him.

A carpool coordinator is responsible for the overall administration of the carpool program, a duty which requires only a part-time commitment. The specific duties of the coordinator should include:

- definition of project objectives and preparation of budget and work program;
- preparation of correspondence from management to employees, announcing the start of the

carpool program and asking for employee support;

- arranging for the distribution of information about the program, promoting company carpooling incentives to employees, and expediting the return of completed application forms;
- responsibility for the preparation of matching lists, the distribution of the lists to applicants, and the arranging of meetings for potential poolers;
- maintaining the program and performing periodic evaluations of it.

Clerical duties are primarily those associated with coding information, distributing publicity materials, maintaining files and answering the telephone. After the program is implemented, one person would be required on a part-time basis for these tasks.

In a vanpool program, the pool administrator has additional duties, including those of:

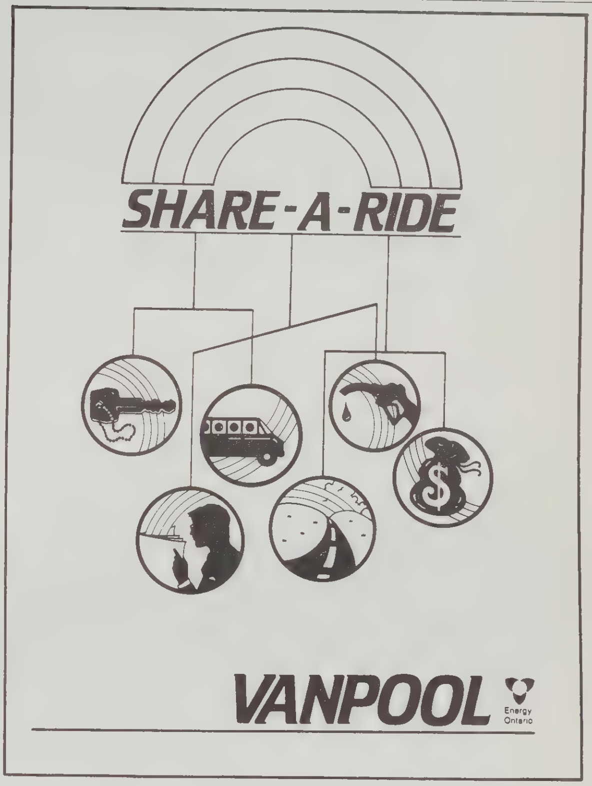
- generating public relations material showing the benefits of vanpooling;
- integrating vanpool and carpool operation;
- selecting drivers;
- supervising route and schedule selection;
- ordering vans;
- supervising vehicle maintenance;
- attending to tax, legal, and insurance issues;
- administering the program.

Figure 4.1

Typical Carpool Promotional Material

Figure 4.2

Typical Vanpool Promotional Material



Promotion — Promotional material should be distributed to employees to make them aware of the benefits of carpooling and, if there is a potential market, vanpooling. Figures 4.1 and 4.2 illustrate typical brochures for car- and vanpooling respectively.

The incentives for ridesharing, having been decided upon by management, should be included in the promotion. The choice of incentives can influence the promotion and marketing of the carpool program and can significantly affect employee participation in the program. The main purpose of promotion is to introduce and explain the concepts of carpooling to the employees and to encourage their participation. There are four basic areas of concentration: preliminary promotion, sign-up publicity, distribution of match lists, and group meetings. In each area, information is distributed by the use of posters, newsletters, and other available media.

The promotional element of the carpool campaign should be aimed specifically at the solo driver and should concentrate on the personal benefits of carpooling. It should:

- remove any negative attitudes of the solo driver toward carpooling;
- explain the individual cost savings of carpooling (auto drivers can save from $200 to $1000 annually on their commuting costs by carpooling);

- explain that there are no legal or insurance problems to impede the formation of carpools;
- explain that signing up and receiving a matching list does not obligate anyone to join a carpool;
- list the community benefits which would result from carpooling.

Following the preliminary promotion to introduce the concept of carpooling to employees and the sign-up campaign to promote enrollment in the carpool program, the employees indicate their interest in pooling by returning their survey forms (Figure 4.3) or pamphlets (Figure 4.1) and are matched into groups by neighbourhood.

For vanpool programs, newsletters, bulletin boards, and any other available media can be used to inform employees about the concept of ridesharing and to provide some details of the program. An endorsement memorandum from senior officials is useful. Promotional information should define:

- general purpose and benefits;
- examples of fares and potential savings;
- opportunity to obtain less expensive, non-commuting auto insurance rates for their personal vehicles;
- degree of municipal support;
- principles of fare calculation and payment;
- driver's responsibilities;
- benefits to the driver and back-up drivers (this might include a free ride for drivers and use of the van during evenings and weekends);
- the comfort and relaxation of being a vanpool passenger;
- community benefits.

Employees can indicate interest in vanpooling by returning the form (Figure 4.2). A fully equipped demonstrator van from a local dealer provides another effective promotional display that can help establish vanpooling as a first-class mode of travel, comparable in comfort to commuting by car.

Market Investigation — A survey of municipal employees should be conducted to determine the degree of interest in ridesharing and to provide information for matching. The survey would determine current commuting patterns, mode, origin, destination, working hours, and ride preferences. Typical survey forms are shown in Figure 4.3.

A potential market for vanpooling usually requires:

- a longer-than-average commuting distance (generally, people travelling distances of over 25 km have produced the most successful vanpools);
- a sufficient number of employees in the same area or along a commuting route (approximately 15-20 people);
- a lack of adequate commuter transit services;
- groups or individuals who have expressed an interest in vanpooling.

For purposes of the preliminary study, an estimate of the market can be made. Using addresses or postal codes available through the personnel records, the number of employees who commute more than 25 km can be determined, and theoretical routes examined to conclude whether or not there is a potential market. It is important to remember that, for success with short trip distances, convenient pick-up spots must be available. For a 25-km one-way trip, pick-up time must be kept to a minimum.

Matching — Matching techniques will determine how employees are enrolled in a carpool program. Matching systems range from simple bulletin-board systems, self-administered by employees, to centralized computer matching techniques. An individual neighbourhood list for each employee is a primary attribute of centralized systems. Municipalities may choose a particular matching technique depending upon the size and location of municipal buildings and the availability of staff. The more successful programs have used centralized matching techniques and have exercised care in maintaining a comprehensive data base.

In the case of vanpools, the administrator will analyze the returns from the interest survey in preparation for matching, route selection, and driver appointments. The most common process is for the administrator to identify those individuals interested in driving, and select suitable candidates. A pool of 10 or 11 participants is then formed for each driver. The pool is drawn either from the driver's immediate vicinity or from locations along a route between the driver's residence and the work place. This matching is normally done by hand. However, if carpooling is being established simultaneously with vanpooling, the same data base could be used and a computerized matching program employed. This matching program is available at the Ministry of Transportation and Communications, through the Share-A-Ride program.

Start-Up Meetings — Lists of neighbouring employees (i.e., potential carpoolers) are given to each employee. A typical list output from the Ministry of Transportation and Communications matching program is illustrated in Figure 4.4. Meetings are then arranged so that interested parties may meet to make arrangements to carpool.

Many people are reluctant to form carpools with strangers. A neighbourhood meeting gives an employee the opportunity to meet, in an informal setting, other employees who are also interested in pooling and who live in the same area. Meetings of this sort are one of the most effective methods of promoting the formation of carpools.

Figure 4.3
Ridesharing Survey Form

1 A 1 2 3 11

SHARE-A-RIDE

You are requested to fill out this card even though you may not be interested in the services offered by the SHARE-A-RIDE program. If you are interested in SHARE-A-RIDE, the information you provide will be used to match you with fellow employees living in your neighbourhood. Participation in SHARE-A-RIDE is voluntary and filling in the card places you under NO obligation.

NAME – Print first name, leave a space, print last name
17 40

STREET NUMBER
41 45

STREET NAME or CONCESSION
47 66

CITY – POSTAL AREA
67 80

2 A 1 2

POSTAL CODE
13 15 16 18

NEAREST MAJOR INTERSECTION TO YOUR HOME
19 46

NAME OF STREET AT CORNER CLOSEST TO YOUR HOME
47 62

65 X 68 69 Y 72 3 A 1 2

PLEASE COMPLETE BOTH SIDES

HOME TELEPHONE NUMBER
15 42

OFFICE TELEPHONE NUMBER
43 50

EXTENSION
51 54

USUAL WORKING HOURS

Arrival Time
Hour : Minute AM / PM
55 57 59

Departing Time
Hour : Minute AM / PM
61 63 65

EXAMPLE
0 8 : 1 5 A M
0 4 : 3 0 P M

USUAL COMMUTING METHOD
67
Fill in number
1. Drive alone
2. Carpool – Drive or ride with others
68 Fill in usual number in car
3. Vanpool
4. Public transit
5. Walk or cycle
6. Other – Specify

SMOKING HABITS
69
Fill in number
1 Non smoker
2 Willing not to smoke while commuting
3 Prefer to smoke while commuting

I MAY BE INTERESTED IN CARPOOLING
70
Fill in number
1 On a regular basis
2. Occasionally
3. In emergency situations
4. Not interested in carpooling

IF I WERE CARPOOLING, I WOULD PREFER
71
Fill in number
1 To be the driver (only)
2 To be a rider (only)
3 To share the driving
4 To drive or ride (no preference)

I WOULD CONSIDER VANPOOLING, IF A PROGRAM WAS OFFERED
72
Fill in number
1. Yes
2 No

PLEASE COMPLETE BOTH SIDES

Each neighbourhood meeting should represent a distinct geographical area chosen to accommodate at least 30-40 interested employees. Preferably, meetings should be held during working hours. A brief presentation by the coordinator should be included, highlighting any incentives being offered to carpoolers, and reassuring the participants that there are no legal or insurance impediments.

For vanpools, a start-up meeting should be arranged for the van drivers and their passengers a week before the van is to arrive. This is the first opportunity for all of the individuals to meet officially as a pool and serves as a forum for discussing details of the program (such as the fare, the route, and various other policies). The vanpool administrator should prepare a proposed route and a possible fare schedule. The pool members may have suggestions on route improvements and should establish among themselves how the fares will be calculated. The administrator's concern is that the total fares equal the total costs. He may distribute a subscription agreement to potential riders before the meeting. This document clarifies the company's and the rider's obligations to the vanpool. Having reviewed this agreement, the vanpoolers will be prepared to discuss and develop policies on such points as:

- responsibilities of the driver and back-up drivers;
- fare collection procedures;
- personal arrangements for substitute riders (the fare pays for a reserved seat);
- responsibilities of riders to notify the driver, in advance when possible, of vacations, illness, overtime, etc.;
- establishment of a chain of communication for notifying the driver of absence (usually a rider calls the person picked up one or two stops ahead);
- the van's route (at this time, the riders may suggest improvements in pick-up order or street routing);
- arrival time (scheduling the van to arrive at work 5-10 min early will allow time for unforeseen delays);
- waiting time per stop (two minutes is usually the limit);
- smoking (some companies have instituted 'no smoking' rules on their vans and have found them much appreciated);

Figure 4.4
Share-a-Ride Neighbourhood List

James Edwards
Sys Research & Dev, Transit Systems
Central building, 3rd floor
Phone: 248-3771

205 Hilda Ave Apt 1001 near Steeles/Yonge Willowdale M2M 4B1 Home: 223-2471 At work 8:30 a.m. to 5:00 p.m.	at Steeles	Interested in pooling regularly Requires a ride Currently drives alone Non-smoker

People below are listed by distance from your home

Joyce Cook on Hilda Ave near Yonge/Steeles Willowdale M2M 1V8 Home: 223-1289 At work 8:15 a.m. to 4:45 p.m.	at Green Bush Rd Office: 248-2671	Lives to the south Within 1 km of your home Would share in emergency situation Prefers to be the driver Currently drives alone Willing not to smoke while commuting
Roy Smith on Moore Park Ave near Yonge/Steeles Willowdale M2M 1M8 Home: 225-7983 At work 8:15 a.m. to 5:15 p.m.	at Fargo Office: 248-7141	Lives to the south Within 1 km of your home Interested in pooling regularly Will drive or ride Currently drives alone Non-smoker
John Armstrong on Connaught Ave near Yonge/Finch Willowdale M2M 1H4 Home: 223-2464 At work 8:00 a.m. to 5:00 p.m.	at Hilda Ave Office: 248-3771	Lives to the south Within 2 km of your home Interested in pooling occasionally Will drive or ride Non-smoker
Mike Davis on Otonaber Ave near Hayview/Steeles Willowdale M2M 2T4 Home: 225-7699 At work 6:00 a.m. to 4:00 p.m.	at Maxome Office: 248-3688	Lives to the east Within 2 km of your home Interested in pooling regularly Will drive or ride Currently pools with others Non-smoker

- policies on use of the radio, heater, etc.;
- agreement on a seating arrangement which will make entering and leaving the van safe and orderly;
- the installation of custom features such as reading lights, stereo music, a game table, or an ice chest to make the trip more pleasant;
- pick-ups. In sparsely settled areas where individual pick-ups would take a long time, pick-ups may be at designated meeting points, such as carpool parking lots along the way. Some passengers may be picked up at their homes and others at roadside parking lots. Remember that riders lose interest if the time spent picking up and discharging passengers is longer than the express portion of the trip. (If the municipality has several branch facilities, they could be designated as vanpool "park-and-ride stops". Each could be considered a pick-up point for employees living near it but working at another facility, where their van is based.)

After the pick-up points are established, the driver should drive the route without passengers to determine the exact travel distance and pick-up times. With assistance from the program administrator, the driver can then establish the van's fares according to the pool policy. The Vanpool Rider List provides a record of all passengers, their addresses, telephone numbers, and pick-up times. The poolers can use this list to define a chain of communication for informing the driver of an absenteeism.

In order to maintain enthusiasm for the program, some firms order the van as soon as likely service areas are chosen, so it can be put into service quickly. Most programs allow the driver to use the van during non-working hours and on weekends. Some companies also allow vanpool riders, if properly licensed, to use the van for daytime personal use, such as lunchtime errands. Thus poolers need not feel stranded during the day.

Monitoring and Evaluation — Carpool coordinators should retain the overall responsibility of maintaining the employee carpool program. This requires only a small amount of their time. A telephone line should be maintained as the carpool information number. A clerk should provide information on the program, maintain files, and process new applications. A budget should be set aside for the necessary staff time requirements, for on-going marketing and incentive costs, and for computer costs if applicable. Annual costs range from less than one dollar to about three dollars per employee.

When special parking privileges or other such incentives are offered to carpoolers, they may be required to register with the program coordinator. The size of the carpool, the date of its formation, and what influence, if any, the program had on the formation of the pool should be noted at the time of registration. This provides a method of monitoring carpool formation.

If a centralized matching technique has been used as part of the carpool program, the files should be updated periodically to ensure that the employees listed on the file still live at the same address and have not changed their working hours. One method of updating the files is to distribute questionnaires to the employees on the list, asking them to make any necessary changes. Once the files have been updated, new neighbourhood lists should be sent to all the applicants on file.

The questionnaire can be combined with a survey to evaluate the effect of the program. A questionnaire to all employees may obtain employee travel characteristics, ascertain whether or not the employee has joined a carpool as a result of the program, and ask for comments on all aspects of the carpool program.

2.4.3 Effectiveness

The development of a ridesharing program for municipal employees is an effective measure to promote the saving of energy. Both individual employees and the community benefit from the considerable savings possible. It is not unusual for a vanpool to take 8 cars off the road and thus save about 20 000 litres of gasoline per year.

A ridesharing program for municipal employees enhances the municipality's image and can be a marketing tool to introduce car- and vanpooling to other employers and to the public in the community. The experience gained by the ridesharing coordinator and other municipal staff developing such a program is also valuable in subsequent programs aimed at this wider market.

2.5 Promote and Support Employer Ridesharing

2.5.1 Objective

The objective of this measure is to familiarize companies with the concept of ridesharing and make it relatively easy for them to establish their own car- and vanpooling programs.

Ridesharing is an attractive strategy to reduce dependence on the single-occupant vehicle for work trips. It offers many benefits to the individual, to employers, and to the community involved, and has been successful in a number of situations. Implementation to date, however, has been limited by a variety of factors.

- The number of employees of most companies at specific locations is below the scale necessary to support a single-employer program.

Without the large scale there are too few matches at the residential end of the trip to justify a program. This is a problem for carpooling efforts but even more so for vanpooling and custom-bus programs. A carpool program generally requires a major employer to have 300 or more employees at a given location with the same working hours. A vanpool program requires 500 or more employees per location and shift.

- The launching of programs depends upon employer initiative. Many employers have elected not to sponsor programs because of the managerial and financial commitments required; a lack of interest or awareness; or a lack of direct, tangible benefits.
- There has been no consistent level of marketing and implementation support at the municipal level.
- With respect to multi-employer programs, several institutional issues, such as legal liability, insurance, regulation of services, service delivery, responsibilities, and employment relationships must be resolved.

2.5.2 Description

Municipalities can assist employers in the community in the development of employer-based and -sponsored ridesharing programs by actively promoting them and providing day-to-day support and technical assistance on a continuing basis. Municipalities can also coordinate the programs of adjacent employers where there are concentrations of firms too small by themselves to support successful individual programs.

The employer-based approach to ridesharing programs is extremely effective because it immediately identifies a population of travellers with shared destinations. This simplifies the task of establishing pool matches to the origin end of the trip. Employer-based programs can be broader than the mere encouragement of car- and vanpooling. Employers may sponsor programs by becoming directly involved in owning or leasing vans in the vanpool program, providing maintenance and operation services, or providing preferential parking as needed.

The design of the employer ridesharing program in the municipality should be based on the findings of the preliminary market investigation (Section 2.3). Meetings would be arranged, by the ridesharing coordinator, with the major employers and groups of employers in industrial areas. Following a review of the market, existing ridesharing, the views of the employers and their employees, and possible alternative programs, an employer-based ridesharing program would be developed. This program could include both car- and vanpooling and would be sponsored by the employers. A pilot program could then be undertaken by the employers with the assistance of the municipality. The pilot program would subsequently be evaluated and expanded to the wider market.

Employer Marketing — The development of an employer marketing program is a key element in the success of employer-based and -sponsored ridesharing programs. Employers must be made aware of the benefits to them so that they become enthusiastic about the program. Employer-sponsored ridesharing programs provide substantial savings to individual employees as well as to the company. These benefits include reduced parking demand, better site utilization, lessened congestion, a stable labour market, and enhancement of the company image.

Parking — Because ridesharing reduces the number of vehicles, parking demand is decreased, resulting in less need for expansion, and reduced maintenance and operating costs. 3M Canada and Bell Canada have been able to save 144 spaces and $55 000, respectively, in recent parking lot expansion because of their vanpooling programs. Because parking demand is reduced, site utilization is also significantly enhanced.

Access — Site access is another problem which can be successfully addressed through ridesharing programs. Many locations of high intensity development, such as the Tennessee Valley Authority (TVA), have been faced with the prospect of widening roads into their site; instead they were able to establish carpool, vanpool, and buspool programs which decreased congestion and saved millions of dollars.

Employee Relations — Business relocation to new sites can raise significant questions regarding traffic impacts and the resultant separation, hiring, or training costs of personnel.

The Westinghouse Canada vanpool program eased the impact of the Company's relocation when it moved to a plant 60 kilometres away. Many of their employees preferred vanpooling to relocation of their residences. In a similar fashion, reducing the extent of site congestion by introducing vanpooling can also help to gain the necessary community and neighbourhood approval for relocation programs.

Labour Market — Car- and vanpooling can significantly increase the labour market which is available to the employer. At the Versatile Manufacturing Plant in Winnipeg, many of the 1300 employees commute from rural areas. Employer-sponsored vanpool programs are viewed as a significant community and employee benefit. Garrett Manufacturing in Rexdale started its ridesharing program to cope with inadequate public transpor-

tation, and now 20% of its employees are in car- or vanpools. Monitoring of employer-sponsored programs also reveals many personnel-management benefits, such as:

- increased safety in journey-to-work transportation;
- improved employee attendance;
- improved punctuality;
- higher morale for vanpoolers and enhanced company communications;
- an increase in employee productivity;
- reduced employee stress.

3M Canada describes ridesharing programs as having improved communications and created dependable and punctual employees. Chrysler Canada has found that 27% of its employees who joined vanpools have displayed improved attendance records and that absenteeism and tardiness have been cut by two-thirds among vanpoolers.

Image — Just as employees display pride in working for a company which sponsors a ridesharing program, the community and general public also perceive an improved company image. This generally conveys an image of a company which is concerned about energy, environmental quality, traffic congestion, and employee benefits (at reasonable or low cost). Chrysler, for example, uses vanpooling as a tool in promoting its product. Also, many oil companies promote their ridesharing programs as concern for energy conservation. Many newspaper articles have been published in praise of the vanpooling programs at Chrysler, 3M, and Bell Canada.

Car- and vanpooling are becoming increasingly popular with private companies. Over 700 companies across North America have sponsored vanpooling programs and many more have carpooling projects. Table 4.1 lists some of the companies with ridesharing programs in Ontario, together with their administrators. These people may be contacted by employers who are considering starting a ridesharing program.

Large employers are the prime target for ridesharing promotional efforts because a single contact can reach a large body of employees with an existing administrative organization. The definition of a large employer can be set by the ridesharing coordinator at between 200 and 500 employees, depending on the municipality. Generally, 300 and 500 employees per shift and location are required for car- and vanpool programs respectively.

The personnel manager or other appropriate person should be contacted. Companies should be urged to appoint a ridesharing administrator who would work with the municipal ridesharing coordinator in the promotion and implementation of employer-sponsored ridesharing. Many of the major employers in Ontario have been contacted by the Transportation Energy Management Program (TEMP) Share-A-Ride program. The municipal ridesharing coordinator can provide liaison between the municipality, the employers, and the Ontario Government to coordinate and extend these initial efforts. Municipalities with a high growth rate or with a new factory opening have an excellent opportunity to promote ridesharing, while the new workers are in the process of establishing their commuting patterns.

Table 4.1

Ridesharing Programs — Employers and Administrators

Employer	Location	Contact	Telephone
Bell Canada	Toronto	Emilio Tacconelli	(416) 598-0069
Chrysler Canada	Windsor	Norman Wheeler Ivo Spadotto	(519) 252-3651 local 2809, 2221
Consumer's Gas	Toronto	David Temple	(416) 492-5469
DOFASCO	Hamilton	Paul Jenkins	(416) 544-3761 local 3515
Falconbridge Nickel Mines	Falconbridge	Bernie Murphy	(705) 693-2761 local 2216
Ford Canada	Oakville	Jack Carter	(416) 845-2511 local 1114
Garrett Manufacturing	Toronto	Len Kellow	(416) 675-1411 local 200
Inco Metals	Copper Cliff	Robert Burke	(705) 682-2861
Manville Canada	Toronto	Judi McStravick	(416) 626-5200
Mutual Life	Waterloo	Les Orth	(519) 888-2209
3M Canada	London	Dawn Scott	(519) 451-2500 local 2220
Union Carbide	Brampton	Hans Vaandering	(416) 792-3210
Westinghouse Canada	Hamilton	Nel Cheeseman	(416) 528-8811 local 6469

Medium-sized firms with 50 to 300 employees, located in concentrated industrial developments, are a secondary target for employer-based ridesharing programs. Groups of adjacent firms in industrial parks may employ more people than do single large employers. Promotion of ridesharing for these firms requires coordination. Ridesharing representatives from each company could meet as a group with the municipal ridesharing coordinator to develop a ridesharing program. Policies, responsibilities, incentives, and other issues could be worked out with the group.

The steps in the development of an employer-sponsored vanpool program are outlined in Table 4.2. Carpool program development could be similar. There are three key meetings in the program: introductory presentation, implementation workshop, and pool formation. The process is similar to that discussed for municipal employees (Section 2.4). The municipal ridesharing coordinator and staff, together with TEMP Share-A-Ride staff (as necessary) would assist the company coordinators with the program.

Presentation materials are an important means of creating interest in the concept of vanpooling and of selling the idea of company-sponsored programs to large employers. Presentation materials (a slide presentation, the Share-A-Ride kit, and a desk-top presentation), are available from TEMP.

The slide presentation is a comprehensive package of 100 slides with text for each. The areas covered are:

- *Introduction* (concerns, energy conservation, definition of vanpooling, scope and popularity of vanpooling);
- *Benefits* (to employers, employees, and the public);
- *Implementation* (vanpooling, carpooling);
- *Share-A-Ride Assistance;*
- *Conclusion.*

This presentation has been used extensively throughout the Province.

Table 4.2

Steps in the Development of an Employer-Sponsored Vanpool Program

Development stage	Implementation steps
Share-A-Ride program introduced to employer	Key meeting 1 (introductory presentation)
Employer has decided to evaluate concept	Preparatory meeting Evaluation study Presentation to management Additional evaluation Presentation to executive Aids provided: slides, manuals brochures, personnel demo van, other
Employer has decided to participate	Key meeting 2 (implementation workshop) Vans ordered
Employer has decided on approach to promoting ridership	Aids provided: slides, brochures posters, employee interest forms demo van, other
Employer has introduced program and distributed material to employees	Additional promotional efforts used: letter from management questions and answers reduced fares for early subscribers
Employer has collected responses	Survey results: cards returned (total) respondents interested (riders, drivers, backup, reserve) cards not properly completed Key meeting 3 (implementation workshop)
Employer has processed data, selected drivers, and matched pools	General information meeting held Drivers and backup drivers selected Pool formation meetings held
Employer has implemented program	Vans delivered Pools operational
Monitoring and evaluation	Assistance as required

The Share-A-Ride kit consists of a folder containing various materials such as the *Vanpool Implementation Handbook*, the *Carpool Implementation Handbook*, the benefit fact sheet, and other pamphlets and information. The name "Share-A-Ride" and a logo and letterhead have been developed for use on all published materials. The Share-A-Ride kit has been used on many occasions throughout the Province and, with the selection of appropriate pieces of media, could be adapted to meet any situation.

The desk-top presentation kit was designed to be used in an office presentation to, at most, a few people. It has been used on a regular basis and has proven to be a very successful presentation device.

The introductory presentations are intended to inform attendees about the concept of ridesharing; the benefits that accrue to employers, employees, and the public; implementation; and the support available for participating employers. These presentations may include an introduction by one or more well-known public officials, a presentation describing the key elements of ridesharing, an overview of the experience of a company with a vanpool program, and a question-and-answer session. The use of demonstration vans and other materials may also be arranged.

The implementation workshops provide one-on-one assistance to interested employers in evaluating and establishing a ridesharing program. Key Meeting 2 occurs after the employer has decided to participate in the program. This working meeting defines the broad aspects of the program by drawing upon municipal ridesharing and provincial Share-A-Ride experience and any constraints defined by the employer. Key Meeting 3 is another working meeting between the employer and the municipal ridesharing staff to focus on the results of the employee survey, identification of high potential areas for vanpools, and allocation of the vans.

Evaluation and Monitoring — The municipal ridesharing coordinator should develop a data management system to monitor employer progress and collect data for program evaluation. This would establish a record of ridesharing program assistance to individual employers which would include:

- the master list of employers in the municipality by location, with number of employees;
- employer-contact record forms for each employer contacted in the program, including the name, address, and phone number of the company, the names of the actual people contacted, and the ridesharing coordinator appointed by the company, together with their phone numbers, the status of the program at the company, and general information on employment, parking, etc. (a record of each contact between the municipal ridesharing staff and the company);
- an employer status report for each company (a checklist similar to Table 4.2 which indicates when the various milestones in the program have been reached);
- correspondence with employers.

It is suggested that these files be input into a word processing system so that they can be updated with a minimum of effort. In a large system an alternative approach would be to use a computerized file system.

An evaluation process should be established to review the employer ridesharing program. Information may be collected to assist in the evaluation: a before-and-after survey of a random sample of employees to quantify their attitudes towards ridesharing before and after the promotional period; a detailed debriefing of the company ridesharing coordinators to assess the effectiveness of the program's approach and its effectiveness in meeting their needs; and other surveys of car- and vanpoolers.

2.5.3 Effectiveness

It has been estimated that a comprehensive employer-based program of ridesharing in a municipality can reduce energy consumption by up to 3% in a region. This effectiveness in reducing energy consumption depends on the size of the municipality, the level of promotion and support given to the program, and other factors.

Critical ingredients in the response of companies to an employer-based ridesharing program are the attitude of management and the potential company benefits. The most receptive firms are those that:

- operate in competitive labour markets and employ highly skilled workers;
- are involved with high-technology work that requires research, development, and innovation;
- are located in suburban areas that have limited conventional transit services;
- are planning plant expansions that will entail costly parking-lot construction.

2.6 Promote, Support, and Monitor Area-Wide Carpooling

2.6.1 Objective

The objective of this measure is to encourage carpooling in the municipality to the widest extent possible. The level of effort will depend on municipal policy and the budget and staff available. This is a more difficult market to deal with and requires much more effort than employer-based programs to obtain the same result.

2.6.2 Description

A comprehensive area-wide approach may encompass a carefully balanced program of informational and promotional campaigns, provision of a matching service, incentives for car- and vanpooling, or disincentives for single-occupant vehicles.

This program may be directed at all residents of the community, using enclosures in utility bills to convey information and distribute survey forms, etc. The ridesharing coordinator would develop the program, based on the market analysis previously discussed. The promotion would be aimed primarily at the residential end of the trip (i.e., recipients of utility bills). The program would be similar in many ways to that described for municipal employees (Section 2.4), but on a larger scale.

Promotional activities may be used to inform people, to promote the concept of ridesharing, and to assist the general public in understanding the program. Promotion can include posters, bumper stickers, and mailings; radio, television, and newspaper announcements; speeches, displays and seminars for volunteer groups; and use of the educational system.

Carpool matching is a means of facilitating the gathering together of origins, destinations, and times of travel so that people can find others with similar travel habits. Matching techniques may be either manual or computerized. Computerized techniques are generally useful when large areas are covered, and a great number of applicants are anticipated. Manual techniques are generally most satisfactory for small to medium-sized areas with relatively few applicants.

Another approach to area-wide ridesharing involves the establishment of a neighbourhood ridesharing approach. Pooling for transportation of school children, for example, is a long-established tradition. This concept can be enlarged to include shopping trips, trips to churches and school facilities, or other group activities. A coordinated program with a central phone bureau, posters, and advertisements could be a good way of promoting and encouraging such a neighbourhood ridesharing program. The municipal ridesharing coordinator could work with the community ratepayer groups, Home and School Associations, or other neighbourhood organizations to establish a neighbourhood program.

Carpooling Characteristics — Carpooling is the most common form of ridesharing today. More people going to work in Ontario municipalities ride in cars than in mass transit. The existing magnitude of carpooling and its informal and flexible characteristics suggest that it will be the major component of any municipality's ridesharing program.

Observation of carpooling in recent years reveals that there are several distinct operating arrangements used: the same person always drives; driving responsibilities are rotated; or the commuter is dropped off by a member of his or her household.

The high cost of gas is the principal reason for signing up with carpool programs. Not liking to drive is also a frequent reason, particularly in winter. Since cost is a major factor, the attractiveness of carpooling increases as a function of distance. Reasons for not pooling include availability of convenient transit, the need for a car during the day, lack of suitable nearby passengers, or variation in quitting times. Carpools often break up when pool members move, or change jobs or working schedules.

The potential carpooling market should be identified for a particular municipality during the market analysis (Section 2.3). The marketing program can then be aimed at those sectors likely to be most receptive.

Promotion and Marketing — Three different targets can be identified for carpool promotion programs:

- the general public;
- employees of specific employers or employer organizations, or multi-employer work locations;
- identified single auto occupants.

An area-wide carpool promotion campaign aimed at the general public may be undertaken by sending carpool request forms to homes with hydro, water, or telephone bills. An advertising campaign may follow with billboard ads, radio and TV announcements, and full-page ads in the daily and weekly papers. Supplies of forms may be sent to post offices, Chambers of Commerce, private businesses, and other agencies. Typical forms are illustrated in Section 2.4.

People interested in carpooling are asked to return the completed request form to the municipal ridesharing coordinator. A list of people who live and work close to the respondent and have comparable work start-times is then sent to the applicant, including phone numbers and addresses.

Letters may also be sent to applicants where successful matches are not possible. Follow-up questionnaires may be sent out to people who received matches, to monitor the results of the program.

Continuous carpool marketing, matching of customers, and monitoring of existing pools at multi-employer work locations is needed. This is often missing in employer-based programs, which are typically mounted as one-time campaigns to increase carpooling. Some continuous matching occurs from the passive matching activities of a few employees but little is known about the results of this effort.

The municipal ridesharing coordinator should be responsible for continuously marketing carpooling to firms that have used the service, seeking out new firms, and putting a program together for groups of firms located in close proximity to each other.

A third approach to carpool promotion is to identify solo drivers. This method can be carried out at a bottleneck such as a congested bridge. A licence-plate trace may be conducted, and the names and addresses of the owners obtained from the Ministry of Transportation and Communications' vehicle records. Drivers would be grouped into lists of those making similar movements at approximately the same time period. This list could then be sent to the drivers (owners) with the suggestion that they contact others on the list to form a carpool.

The marketing strategy for a carpool program should seek to actively arrange contacts between persons interested in participating. The burden of contacting "matched" persons who have identified themselves as interested in a carpool appears to be a major hurdle for many potential participants. The obstacle of a cold call to a stranger contributes to the low level of contact made after names are supplied and can be eliminated through this practice. The focus of marketing programs should be on convenience, economy, flexibility, and parking incentives.

Marketing may be designed to help expand the data base (registered candidates for matching service and carpool formation) and oriented toward education (for instance, what it costs to commute in a single-occupant automobile), attitude change (making carpooling an acceptable value and commuting mode, and helping to alleviate fears connected with carpooling), or implementation (three easy steps to form a carpool).

Other marketing techniques, especially those utilizing the various media, can be effective if a comprehensive approach is used. For instance, an animated 30-second TV spot specifically promoting carpooling could be used in conjunction with roadside signs and would help to reinforce the suggestion that people utilize the service.

Carpool posters and an 'employer kit' with do-it-yourself materials can help to involve small employers more in getting their employees signed up for carpooling. Distribution of posters and application forms at gas stations, in utility bills, and at banks and other high-volume locations could also be beneficial. Past experience has shown a real increase in mailed-in applications from areas blanketed with brochures.

Incentives — Incentives for carpooling are needed. A variety of incentives are now being successfully used, and others should be tried to encourage people to rideshare. These are primarily directed at making parking or movement to work more attractive for carpoolers than for people who drive alone. Parking incentives include:

- preferential priority parking for carpools, close to the employee entrance (controlled by employers or building owners/managers);
- reduced parking charges for carpools where there is a parking charge (controlled by public agencies, some employers, and lot or ramp owners);
- parking permits for carpools generally but especially where parking is limited;
- financial incentives for carpooling, such as insurance discounts.

In large employee parking lots, priority or preferential parking areas can be established at the best location (close to employee entrances), thereby saving carpoolers 5-10 minutes a day by "beating the rush," and reducing their time in inclement weather. Priority parking for carpools in enclosed facilities also offers advantages over less convenient, outside parking areas.

Another major public incentive focuses on giving carpools, together with buses and vanpools, preferential access to freeways and bridges, or around a bottleneck. These incentives can be highlighted in the marketing material.

Since the cost of commuting is an overwhelming reason for starting a carpool, incentives that would further reduce commuting costs would probably be the most attractive. The municipal ridesharing coordinator should ask local merchants and service stations to provide discounts on tires, tune-ups, etc. for carpool members. Because of the potentially large number of customers that could be involved, it is possible that a discount system could be extended to a number of dealers of automotive products and services who might be interested.

Such an incentive program would require registration for identification purposes, with some form of "membership card" issued by the municipal ridesharing coordinator. One requirement should be registration in the carpool matching program for those carpools already formed, whose members have never signed up. This has the benefit of

adding names to the data base for matching purposes and might also help in obtaining more accurate information on the number of carpools in the municipality.

Matching — Matching is an essential feature in establishing carpooling programs. To provide an efficient service, it is necessary to find a match for every applicant as quickly as possible and to register sufficient numbers of "drive-alone" commuters to ensure that match. The provision of matching service and maintenance of a data bank of applicants is the most expensive part of an area-wide carpool program. The service should be provided free of charge to potential carpoolers, however.

By calling a special carpool number and giving name, address, phone number, and commuting information to the municipal ridesharing representative, the interested caller receives names of individuals in the data base with similar work-trips. These names can be provided while the caller is on the phone, if so desired. Then, as soon as possible, a computer printout, along with other information on carpooling, may be sent to the caller, giving all the possible matches. Individuals can also receive the match list and information by mailing in the postage-paid applications distributed to employers and high-pedestrian-volume locations. Of course, all individuals requesting matching services are added to the data base so their names can be matched with future applicants.

The time it takes from the receipt of a carpool application by the municipal ridesharing coordinator (either by phone, mail, or employer campaign) until the applicant receives the computer match list should be kept to a minimum, in order to respond to the applicant when interest is highest. Ideally, turnaround time for the printed list should be within two days.

The Ministry of Transportation and Communications carpool matching program described in Section 2.4 was designed for employer-based ridesharing. Some modifications would be useful in area-wide applications because of the various employment locations.

It may be necessary for the ridesharing coordinator to hire additional staff, especially for phone matching and follow-up assistance, in order to be more directly involved in carpool formation. As the number of applications increases, the work load on the municipal ridesharing coordinator's matching service staff also increases. Some of the load may be eased by temporary help at times when rising costs, gas shortages, and aggressive marketing or carpool incentives keep the registration rate high.

For efficient matching, it is important to maintain a current data base of people wanting to rideshare. People move, change their work hours, phone numbers, and jobs, or simply lose interest. These names should be removed from the data base as quickly as possible. As a means of ensuring current and accurate data, the municipal ridesharing coordinator should send an updated match list 6 months after a person's enrollment, along with an update/new enrollment form. This form would have all the person's commuting, residence, and work information on it. If all the information is still correct and the person still wishes to be in the program and receive match lists, the form would simply be dropped in the mail. Any out-of-date information could be corrected at the same time. If the form is not mailed back to the municipality, that person's name would be removed from the program.

2.6.3 Effectiveness

The greatest increases in ridesharing will come from carpooling programs, rather than from vanpools or paratransit, because of the relative simplicity of carpools and the effectiveness achieved in terms of cost savings and reduced energy consumption with as few as two or three people per pool. It is easier to match two commuting patterns than ten, as is required by a vanpool.

Carpool programs that are employment-based and employer-supported tend to be more successful than those directed at the general public or to identified solo auto drivers. The applicant response rates of people who are contacted by their employers is generally higher than in an area-wide program. The marketing and matching effort is also less expensive for employer-based programs because of the single employment location. However, there is a large market of potential carpoolers not employed at large firms. They must not be ignored.

The potential effects of modal shifts are illustrated in Table 4.3. The impacts of a number of carpool demonstration projects in cities in the United States are shown in Table 4.4, including the gasoline saved, reduction in kilometres of travel, and cost effectiveness of the programs.

In general, even though total impact on work vehicle-kilometres of travel was quite low (an average of 0.7% for the cities in Table 4.5), cost effectiveness at 2.4¢ per veh-km of travel reduced makes area-wide ridesharing one of the most efficient energy-conservation measures. Compared with other measures, the cost-effectiveness of ridesharing programs is outstanding, in many cases costing less than one cent of public funds per veh-km of travel reduced. Depending on the length of the work-trip and the number of riders in the vehicle, commuters can save between $300 and $1300 per year in reduced transportation costs. Region-wide energy consumption can be reduced by approximately 3%-5%.

To ascertain the estimated energy impacts of ridesharing based on computed litres per trip, the savings (or costs) in terms of annual fuel consumption are illustrated under various assumptions in Table 4.3. While diversion to bus transit yields greater savings, the likelihood and the opportunity for diversion in a given metropolitan area are more severely constrained for bus transit than for carpool options.

Table 4.3

Energy Effects of Modal Shifts

Base condition

Mode	Number of trips	Fuel consumption (L) Total	Fuel consumption (L) Per trip
Bus	78 952	40 223	0.51
Carpool	24 550	37 909	1.54
Drive alone	54 246	154 309	2.84
Other	8 025	—	—
Total	165 773	232 441	1.40

Annual fuel consumption estimates for 10% shift between modes

Shift From	Shift To	Consumption (L)	Saving L	Saving % of base
Base	(No change)	232 441	—	—
Drive alone	Carpool	225 318	7 123	3.1
Drive alone	Bus	219 658	12 783	5.5
Bus	Carpool	240 679	−8 238	−3.5
Bus	Drive alone	251 035	−18 594	−8.0
Carpool	Drive alone	240 424	−7 983	−3.4
Carpool	Bus	229 864	2 577	1.1

Annual fuel consumption estimates for one person shifting modes

Shift From	Shift To	Consumption (L)	Saving (L)
Base	(No change)	232 441	—
Drive alone	Carpool	231 832	609
Drive alone	Bus	231 346	1095
Carpool	Bus	231 955	486

SOURCE: *Energy Effects of Carpooling: The Vancouver Case*. Transport Canada; November 1978.

2.7 Develop 3rd-Party Vanpool Program

2.7.1 Objective

The objective of this measure is to extend vanpooling beyond the initial employer-sponsored program by providing vehicles, insurance, administration, and organization to people who work for employers who are reluctant to sponsor a vanpool program. This is in contrast to the employer program, where an employer owns or leases vehicles for his employees; supplies insurance, marketing, administration, and subsidies; and where not all costs incurred are built into the fare structure.

One of the factors hindering the development of vanpooling has been that the commitment required of an employer is substantial, involving financial and managerial resources. Many employers are reluctant to start programs for a variety of reasons, including:

- lack of motivation, as commuting is not a pressing business problem;
- lack of financial resources or unwillingness to allocate scarce capital to vans;
- dispersed employee residential patterns, resulting in few close-by matches. This limits the number of pools that can be formed or results in pools that have excessive pick-up times;
- lack of management and administrative personnel to run such a program;
- implications for collective bargaining;
- inability to serve all employees at all locations for multi-location companies;
- concern about providing a service attractive to only a small proportion of the employees;
- lack of know-how;
- unwillingness to subsidize;
- concern about legal liabilities.

2.7.2 Description

The municipal ridesharing coordinator would analyze the situation, discuss it with employers, and decide whether a "third-party" program is suitable. The next step is to consider the various options of providing for adequate management of the program, of gaining employer support, and of effectively coordinating the simultaneous delivery of the service to several employers with varying levels of interest. Options in developing a third-party program include the following:

- A single-employer-sponsored vanpool program is expanded to include neighbouring employees.
- The municipality acts as the third party, supplying vehicles, insurance, and administration; organizing, and operating the program.
- The Ontario Van Pool Organization Limited (OVPO) acts as the third party.
- A contractor, perhaps a local school-bus and charter operator, acts as the third party on behalf of the municipality.

In a single-employer-sponsored vanpool program expanded to carry employees from neighbouring companies, the sponsoring employer would supply all program components such as vehicles, insurance, and administration, and would recover costs through fares. No profit would be made.

Table 4.4

Impacts of Areawide Ridesharing Programs

Location	Impacts of VKT reduction: Number of permanent new carpoolers	Daily VKT reduction per new carpooler	Estimated annual VKT reduction ('000)	Estimated % reduction in work VKT	Estimated annual energy saved (L)	Cost effectiveness of ridesharing programs: Annual project cost ($)	Estimated annual cost per new carpooler ($)	Estimated cost per carpooler-trip ($)	Estimated cost per vehicle-km reduced ($)
Direct impacts on carpool-matching applicants (selected)									
Denver	1 419	14.8	4 800	0.2	844 000	125 000	88	0.19	0.011
Connecticut	2 791	35.7	23 000	—	4 209 000	65 000	23	0.05	0.001
Boise	118	12.1	320	0.2	61 000	—	—	—	—
Minneapolis	4 507	27.4	28 300	0.6	5 182 000	60 000	13	0.028	0.0008
Augusta ME	89	7.7	160	—	30 000	—	—	—	—
Omaha	1 210	12.7	3 500	0.3	647 000	8 000	69	0.15	0.010
Seattle	2 175	10.8	5 400	0.1	988 000	215 000	99	0.22	0.017
Washington DC	10 267	12.9	30 400	0.4	5 564 000	110 000	11	0.024	0.002
Average (26 sites)	2 071	16.9	9 650	0.3	1 752 000				
Broader impacts of ridesharing programs (selected)									
Portland	7 338	14.3	24 100	1.0	4 417 000	190 000	26	0.06	0.003
Boise	600	12.1	1 670	0.8	307 000	45 000	75	0.16	0.011
Boston	8 689	12.4*	24 800	0.3	4 530	325 000	37	0.08	0.006
Milwaukee	8 080	9.1	16 900	0.7	3 092 000	100 000	12	0.027	0.003
Average (6 sites)	6 732	13.0	20 400	1.2	3 732 000	140 000	47	0.10	0.006

SOURCE: Wagner, F.A. *Evaluation of Carpool Demonstration Projects*. Prepared for the Federal Highway Administration; October 1978.

* Estimated.

This scenario is possible if a vanpool already exists in an area and an employer is willing to expand it, or if a large employer has some smaller neighbours. The majority of vanpoolers must be employees of the sponsoring company in order to comply with the Public Vehicle Act.

The municipal ridesharing coordinator could assist in the organization of the program by coordinating adjacent employers, as noted in Section 2.5. This method may be appropriate for some sites but may be unsuitable for others.

In a third-party vanpool program, the employer could have either of the following relationships with the provider. He could:

- support and encourage the program by actively participating with the third-party provider in marketing the program to the employees;
- contract with the third-party provider to manage the program for the employees as a "single employer" program. In this case, a legal agreement would exist between the employer and the provider.

The third-party provider may be OVPO, the municipality, or a local contractor (bus operator, etc.) acting on behalf of the municipality. OVPO has standard operating procedures which would be followed. Contracts with independent operators would have to outline appropriate procedures.

Municipal Third-Party Program — If the local-contractor method is utilized, the contractor could be offered public financial support (to mitigate the risk of program termination) and a start-up fee to cover the differences between fare income and expenses (due to lack of scale until the program reaches a break-even point).

This method has strong implementational and operational advantages. It would operate independent of the employer. Pre-selection of the contractor would enable the complete package to be delivered from day one. Further, the program is set up so that after break-even, no public support is required and a successful business is created, which can proceed independently and maybe even expand. Replicability is easy and continuity is an advantage.

The municipal ridesharing coordinator would design the program and outline the functions and responsibilities of the participants: municipality, employer, contractor, employees. Some of the considerations in the program include:

- general promotion
- marketing and matching
- removal of risk
- van provision
- fare administration

It is suggested that the municipal ridesharing coordinator and staff be responsible for arranging for a contractor, identifying the areas of greatest potential, conducting a marketing campaign to solicit participation by individual employees, matching interested employees into groups of 9 or more and selecting one as the driver, fostering the formation of pools, and monitoring the progress of the program.

It is further suggested that the program include a contractor who will lease insured vans to the driv-

ers, provide arrangements for maintenance of the vans, and administer the operations part (as opposed to the marketing part) of the program.

In order to encourage vanpooling, the lease between the contractor and the driver can be co-signed by the program coordinators so that the driver can return the van on 30 days notice without personal penalty. The coordinator would then reassign the van to a new pool, pay the interest charges while the van was not in use, or have the contractor terminate the lease and dispose of the van, in which case an early termination penalty may be payable.

The actual implementation plan would consist of staffing the program, establishing office and support arrangements, preparing marketing materials, developing contracts and agreements, marketing the program, establishing pools, providing vans, and administering fares. The major agreements and contracts which must be developed are:

- a contract between the program and the contractor, related to scope of work, performance, and fees;
- a lease agreement with an "early termination" clause, between contractor, driver, and program;
- a rider agreement between rider and driver.

The initial program should be designed to serve work trips which have at least one end within the municipality and which are related to places of employment where company-sponsored vanpool programs are not feasible. This includes small employers (less than 500 employees) and multi-employer complexes (office buildings, industrial malls, etc.). Program staff would identify employment sites with potential for vanpooling.

Marketing materials necessary for presentations to employers, or to groups of employees; and the response forms used in the matching process must be prepared. The team would market the idea of vanpooling in the candidate sites, elicit responses from employees, and endeavour to group respondents into pools. The marketing team would select appropriate individuals as drivers and provide them with lists of potential riders. The onus is then on the driver to contact the individuals on the list and form a pool. If a potential pool is identified but no driver is available, the marketing team would attempt to find a driver. Basically the function of the marketing team is to sell the concept to employers and employees and to foster the formation of pools by matching interested individuals, selecting drivers, and smoothing the process for the pool members.

The removal of risk is an essential feature of the program, so that the driver will be able to return the van to the program on 30 days notice. This is contained in the lease agreement between the driver and the program, which describes in detail the responsibilities of each party. Program staff will explain this agreement to potential drivers during the marketing phase and again before the agreement is signed.

The contractor will obtain commuter vans, and assign them to those drivers identified by program staff. The vans will be insured by the contractor and will be equipped according to specifications in the agreement. The agreement will include a provision for back-up vans to be kept on hand. The number will depend upon the number of vans placed.

The contractor will also be responsible for the administration of fares and will provide financial reports to the program staff.

2.7.3 Effectiveness

The effectiveness of third-party vanpool programs will vary among municipalities according to the size and location of employers. Third-party programs should be investigated after employer-sponsored programs are fully developed.

2.8 Provide Subscription Bus Service

2.8.1 Objective

The objective of this measure is to identify situations where subscription bus service would be more energy-efficient and cost-effective than conventional transit or ridesharing, and to design a custom-tailored subscription bus service to meet the specific needs of the area.

2.8.2 Description

The municipal ridesharing coordinator should work with the municipal and regional transit managers to assess the need for subscription buses. The ridesharing market analysis and discussions with employers, together with transit passenger loads, costs, revenues, and other information must be taken into account.

Subscription bus service is usually developed for commuters who are not adequately served by conventional transit services (including charter or inter-city operators) because they live and work in low-density areas, or make commuter movements which do not coincide with the regular routes. In contrast with conventional bus planning, customers are identified and signed up before service is provided. As a result, specialized services using a large bus can be custom-tailored to serve people who will be regular riders, usually for the trip to and from work. The route, schedule, etc., depend on the riders. If several vanpools operate along the same route, this might indicate

a need for a subscription bus. Characteristics of subscription bus services include:

- relatively high-density employment destinations (most are central-business-district-oriented)
- relatively high-volume collection points, such as new town centres, rural free-standing communities, high-density residential complexes, or park-and-ride locations with at least 35-50 interested commuters;
- an express component to the trip;
- transit times which do not exceed 1.3 to 1.5 times the time a trip takes by auto;
- involvement of an initiating sponsor;
- special features such as guaranteed seating, door-to-door delivery, air conditioning, reclining seats, etc.
- continued monitoring and tailoring of service to meet customer desires, schedule reliability, and back-up service when vehicles break down;
- a fare which is less than the cost of driving an automobile;
- committed riders who "purchase" multiple rides in advance.

Subscription services have emerged, propelled by user demand, in areas where gaps in conventional transit exist, where there is no conventional transit, or where special riding features are desired.

- Most programs are organized by a private operator or community group rather than by transit authorities.
- The vehicles are typically supplied by contract to the organizing group. Transit authorities act as vehicle suppliers under contract.
- Most programs are not subsidized.
- The fares reflect the premium service. Fares of $1 per trip and above are the most common.
- Most programs focus on long trips (20-60 miles one way).
- The services, while effective, have low "market shares" of the total trip movement.

There are several reasons for the focus on the long trip. Since many of the cost components are fixed, costs do not increase significantly and fares become relatively more attractive as distance increases. The collection function becomes a smaller fraction of total travel time because of the greater amount of time required to travel a long distance.

Where there appears to be a market for subscription bus service, the municipal ridesharing coordinator should meet with employers to obtain their support (including financial support if possible). The ridesharing coordinator and transit manager can subsequently design the subscription bus service. Some recommended features follow.

- Fare policy should be suitable for the committed rider, with advance (perhaps monthly) tickets.
- The route structure should be based on rider convenience and modified as necessary to reflect rider demands.
- The equipment used should be the best available, with padded seats and air conditioning as a minimum. C.B. radios in buses are also desirable.
- The same driver should be assigned each day and some schedule flexibility should be permitted.
- A bus captain should be selected from among the passengers. This person would coordinate with the driver and implementing agency to ensure passenger loading is satisfactory, route/schedule modifications are made when needed, and complaints handled. This person would ride free.
- The passengers should be informed that minimum ridership levels must be maintained in order to continue service.
- The basic route policy should be to minimize total passenger time by doing the door-to-door pick-ups first, and then serving convenient park-and-ride and common collection points, where a majority of passengers will meet the bus.

2.8.3 Effectiveness

The effectiveness of subscription bus service will vary with the situation in each municipality. It is a specialized application suitable for some situations. The major issue in both energy efficiency and cost-effectiveness is the load factor. The majority of seats on the bus should be occupied. Cost and energy consumption should be compared with the alternatives of vanpooling and conventional transit when the program is designed, to determine its effectiveness.

2.9 Provide Paratransit

2.9.1 Objective

The objective of this measure is to investigate the use of paratransit for special needs in small communities or in the fringe areas of large communities, where it may be more cost-effective and energy-efficient than conventional bus service.

2.9.2 Description

Every situation is unique. Potential applications of paratransit must be examined in detail before implementation.

General criteria which can be used in the evaluation of paratransit service are as follows:

- Energy consumption should be less than that required to provide regular transit service.

- Cost should be lower than that of providing regular transit service.
- Capacity and level of service must be adequate to carry the passengers.
- Management and administration should provide simple, effective control of service and accounting.

It is suggested that a reasonable level of revenue should be recovered from bus operations in the off-peak periods. Two main criteria have been used in other municipalities.

- Revenue:cost ratio should exceed a certain percentage.
- Deficit per revenue passenger should not exceed a set figure.

These criteria might be used to determine when service should be terminated or a less expensive form of service provided. Similarly, they might be used in planning service into new areas in conjunction with projected cost and revenue figures. A comparison of vehicle characteristics and costs is shown in Table 4.5.

The major issue in substituting paratransit for conventional buses is the potential overloading of vehicles. A sedan taxi can carry five passengers but, for operational reasons (loading and unloading), it would appear that a maximum of three passengers can comfortably be accommodated. Vans are manufactured in two basic sizes: the short van with 10-12 adult seats, and the long-body van with 15 adult seats, including the driver's. When more than two paratransit vehicles are required to replace a single transit bus on a route (except on rare occasions such as during stormy weather, etc.) the route should not be considered a candidate for paratransit.

Fare collection and user charges should be compatible with existing practice in the municipal transit system. Fares for fixed-route paratransit service should be the same as for regular transit. If a demand-responsive service is provided, a premium fare should be charged.

The options for cash handling depend on the type of vehicle. Vans could have a cash box permanently mounted inside. This method would eliminate handling of cash by the operator, provide accounting control, and provide ridership figures in the same manner as the regular transit service. Taxis have no room for a fare box. Cash would have to be counted by the operator and reported, in order to monitor ridership and provide accounting control. Payment to the contractor could be either a fixed rate, in which case revenues would be retained and deducted from invoices, or a lower fixed rate plus retained revenue.

Vehicles would be clearly identified by metallic signs with the municipal transit logo and the name of the service. Vehicles should all be the same type and colour so that passengers become familiar with them.

One alternative for paratransit would involve a contract van service as a replacement for fixed-route bus service running on the same route and schedule in the off-peak hours. This would save money because of the smaller vehicle, lower operating and fuel costs, and part-time labour rates. Marginal routes, which are too expensive to serve with regular transit (such as suburban low-density areas in the off-peak periods), could be served while meeting reasonable cost:revenue targets.

A second option, the use of the shared-ride taxi on a fixed route, would be applicable on very-low-volume routes. Some flexibility can be achieved by radioing a second vehicle in overload situations but this causes delays and presents accounting difficulties not present with the larger-capacity vans.

Table 4.5

Comparison of Vehicle Characteristics and Costs*

	Conventional bus	Fifteen-passenger van	Twelve-passenger van	Standard taxi sedan
Number of seats	40	15	12	6
Design load (passengers)	82	10	8	3
Maximum load (passengers)	103	14	11	5
Capital cost ($)	100 000	13 500	12 000	9 000
Service life				
Years	12–18	3–5	3–5	3–5
Kilometres	560 000	240 000	240 000	240 000
Fuel consumption (km/L)	2.5	5.7	5.7	6.4
Operator's wages ($/h)	8.52	5.00	5.00	5.00
Fringe benefits (%)	42	20	20	20

* Estimated 1980 costs are for comparison purposes only; actual fuel consumption, service life, etc., depend on use.

Demand-responsive, subsidized shared-taxi operation as for *dial-a-bus*, but using the taxi operator's dispatch system, would be a third option. Fares could be the same as regular transit fares plus a small premium for door-to-door service within a specified area. This option would provide better service in the designated area but at a higher cost to both the user (in terms of premium fare) and the municipality (in terms of increased subsidy). Accounting, monitoring, and control would be more difficult than for fixed-route service. The service would also be in direct competition with the regular taxi service.

2.9.3 Effectiveness

The effectiveness of this measure will depend on the individual situation. The key issue in both cost and energy terms is the passenger load factor.

2.10 Policy Measures to Support Ridesharing

2.10.1 Objective

The objective of these measures is to reinforce ridesharing programs by offering incentives to high-occupancy vehicles (and disincentives to single-occupant vehicles).

2.10.2 Description

The municipal ridesharing coordinator would encourage employers to adopt policies and to help to shape municipal policy with regard to measures which would encourage ridesharing. Some examples of such policies:

- removal of parking-cost subsidies by employers;
- institution of parking-cost subsidization by employers for carpoolers but not for single-occupant vehicles (SOVs);
- preferential parking spaces for car- and vanpools;
- park-and-ride lots for car- and buspoolers;
- flexible hours;
- auto-restricted zones;
- parking permits for high-occupancy vehicles;
- reserved HOV lanes on freeways and arterials;
- priority ramp metering.

The zoning bylaws and building development approval process might be modified by the municipality to require new employers to develop programs that will limit the traffic burden they impose on the local street system. Prospective employers can implement vanpool services, subscription bus services, preferential parking, staggered work hours, or whatever they determine to be the most economical means of restricting the amount of traffic on the parcel of land they intend to occupy. Residential developers could also be required to provide neighbourhood carpool areas near arterial routes.

The municipality could insist on a specific level of traffic service and help employers and developers to achieve it through cooperation with ridesharing programs. Additional development might be approved, provided ridesharing programs were developed.

2.10.3 Effectiveness

The effectiveness of these measures depends on the overall parking demand and supply situation. Enforcement is required for some measures. Surveys have shown that single drivers will accept preferential treatments for carpools with three or more occupants, but not for those with only two occupants.

Ontario

Ministry of
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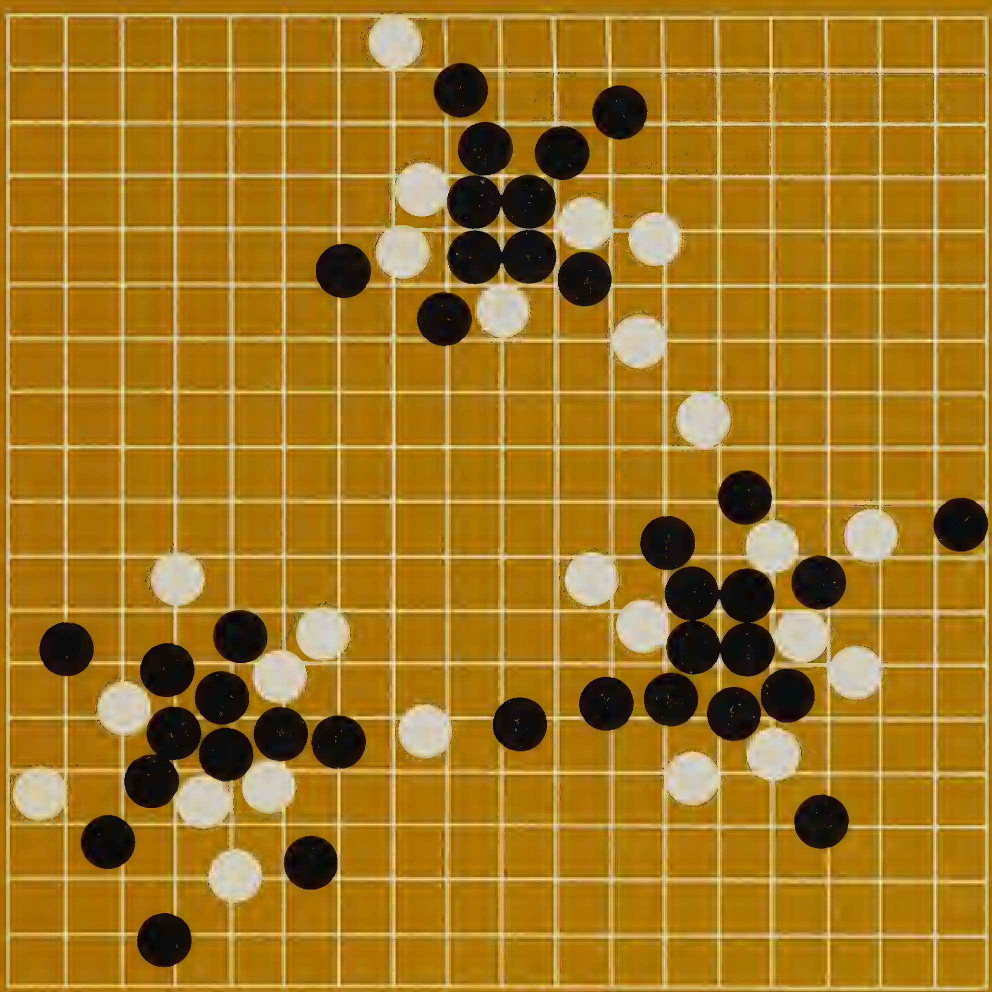
Ontario

Transportation Energy Analysis Manual

5: Travel Demand Management



The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM
Transportation Energy Analysis Manual

5: Travel Demand Management

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Preface

The purpose of the **Transportation Energy Analysis Manual (TEAM)** is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within their municipality. The Manual is organized into ten chapters, which outline the principal technical ways to conserve energy through transportation improvements.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is the crucial public-sector level because these decision-makers deal with the day-to-day activities of the thousands of citizens residing within their municipalities. Energy conservation is an on-going, everyday affair, and the municipality is directly involved.

The **Transportation Energy Analysis Manual** will consist of chapters on the subject areas listed below. The Manual is being produced chapter by chapter as each is completed. These in turn will be updated as considered necessary.

1. Overview and Summary
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Energy Program Management
10. Energy Analysis Methods

This chapter, **Travel Demand Management**, focuses on and highlights travel management techniques which can be used to conserve energy in a specific area.

Additional information on the Manual or on any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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1 Introduction

Energy consumption is affected by the amount of travel and by the conditions under which that travel occurs. By managing travel demand, reductions in vehicle-kilometres of travel or vehicle-hours of travel can be achieved, resulting in lower fuel consumption. The greatest reduction occurs if a trip can be eliminated completely. However, assuming that some travel is necessary, reductions in distance or time travelled are desirable objectives as ways of reducing energy consumption. Travel time, and energy savings, can be achieved by spreading out peak demand and thereby having more vehicles operate at, or closer to optimum fuel consumption speeds.

This chapter discusses measures that are designed to reduce travel demand in total, or at least in the congested peak periods. They include the following actions:

- compacting urban development and integrating land uses (land-use planning);
- spreading peak periods (staggered work hours and flex-time);
- road pricing;
- parking management;
- ridesharing;
- auto-restricted zones.

The following sections describe each of these concepts, present key planning considerations, identify results of recent experience, and set forth guidelines for estimating energy savings.

2 Land-Use Policy

2.1 Strategy and Objectives

Land use is the key to transportation demand and, therefore, transportation energy consumption. This is because land-use patterns and intensities establish the spatial relationships that influence travel volumes, directions, and modes. The types and densities of various urban activities also have particular energy requirements that must be considered. Therefore, application of certain land-use planning policies can result in conservation of transportation energy.

2.2 Description of Measures

Generally, the greater the concentration of activities, the greater the opportunity to provide fuel-efficient transportation services. Such opportunities exist in both large and small Ontario communities.

Local governments have the opportunity to reduce the average length of daily commuting work trips and other trips, and to control land-use planning so that expansion of public transit is facilitated. These activities are essential in enhancing long-term prospects for energy conservation. Reductions in auto travel can be achieved through the integrated planning of transportation and development. This can counter trends toward increasing spread development.

Specific land-use-related transportation energy conservation opportunities include:

- greater density through multi-unit residential development;
- integration of work, residence, and shopping activities;
- community self-containment;
- residential clustering;
- developmental activity along transit routes;
- design which facilitates transit circulation;
- infilling of vacant property.

While this manual focuses principally on transportation and energy relationships, it is important to remember that land-use planning has an impact on a wide range of municipal energy-conservation opportunities. Accordingly, proper municipal energy-conservation planning will consider all factors, including construction, maintenance, and direct energy requirements.

Subdivision Regulations — The importance of examining energy and land-use relationships is apparent in Figure 5.1 — a copy of an Ottawa-Carleton resolution passed in 1979. This resolution calls for an in-depth analysis of energy-saving features included in the subdivision plan prior to its implementation. Similar resolutions should be considered by other Ontario communities.

Figure 5.1

Ottawa-Carleton Council Resolution

(4) September 26, 1979
Carried

WHEREAS in its decision concerning the Regional Official Plan the Cabinet of the Province of Ontario has included in the Kanata growth area the proposed subdivision by Cadillar-Fairview;

AND WHEREAS in making that decision, the Cabinet noted the "provincial significance" and importance of the "energy conservation features" contained within the subdivision proposal;

AND WHEREAS the Cabinet further noted that "proceeding with this energy saving project is a matter of urgency,...(so that the) experience gained may be emulated elsewhere and result in substantial energy savings";

AND WHEREAS Council is in agreement that steps should be taken to reduce both current and future energy requirements of the urban area;

THEREFORE BE IT RESOLVED that the Planning Department be instructed to:

(a) prepare a compilation of desirable energy saving features that may be included in subdivision plan including:

i) improved insulation

ii) reduction of exterior wall area by development of attached or buried housing forms

iii) district heating

iv) housing orientation, window size and location and landscaping features aimed at passive solar heat gains

v) active solar heating

vi) decentralization of commercial and community facilities to reduce travel distances

vii) street layout to encourage use of transit

viii) proximity of employment

ix) development of separated walking and bicycle paths to discourage car use for local travel

x) such other features as the department may consider desirable

(b) report this listing to Regional Council for review prior to distribution to municipalities and developers to encourage the incorporation of these energy saving features in new communities and buildings.

(c) develop suitable guideline for new subdivisions to ensure regional and provincial interests in energy conservation are maintained.

(d) review the Cadillar-Fairview proposal to ensure it contains all the energy saving features reasonably possible.

Transit Planning — Public transit service must be considered at the earliest stages of urban and land-use planning. For example, residential sub-

division design has evolved toward the accepted practice of isolating homes by providing cul-de-sacs, circular internal streets, and other such techniques. Unfortunately, many of these adversely affect the ability to provide efficient transit routings with easy pedestrian access.

Route planning involves difficult compromises between direct routing and pedestrian access. Because transit routing on arterial streets may be removed from residential areas, it is important to provide pedestrian walkways. Similarly, subdivision street patterns, which make use of indirect street systems as a means of reducing through-automobile movements, should be redesigned to allow through-transit movements.

Clustering of facilities, such as for shopping, recreation, or social activities, allows focusing of transit trips. In all cases where physical conditions permit, transit routes should be as direct as possible, and located to provide adequate service to the public without unnecessary duplication.

2.3 Effectiveness of Measures

Several studies have quantified the energy consumed by various development densities.

Costs of Sprawl — The *Costs of Sprawl* study, carried out for the U.S. Council on Environmental Quality, isolated density from neighbourhood age, obsolescent design, and low-income population, and measured the important consequences of urban form [1]. Detailed estimates of the energy, environmental, capital, and operating costs were made of six hypothetical new communities — each containing 10 000 dwelling units, each of which housed an "average" urban fringe population mix and was constructed in a "typical" environmental setting. The six communities varied by density (high, medium, low) and community design (optimal, typical). At the extremes were an optimally designed high-density community (19 units per net residential acre) and a "typical" low-density community (3.5 units per acre).

The analysis dealt with residential heating and air-conditioning, and with automobile usage. The well-designed community was found to be optimal with reference to the four key indicators examined, and the typical low-density community was least desirable. The overall energy consumption of the well-designed high-density community was 44% less than that of the typical low-density community.

In contrast, Altshuler points out that many of the energy savings reported for high-density developments dissolve upon close examination [2]. He indicated that the 44% savings in energy usage for space heating and air-conditioning reflected the different indoor space standards utilized:

> "Overall, the high-density community had 34% less residential floor space than the low-density community, and this accounted for five-sixths of the claimed energy savings...
>
> "If one holds dwelling unit size constant, and allows only 20% of the claimed auto-travel savings (but still levies no charge for mass-transit energy usage), the energy-demand differential between the well-designed high-density community and the typical low-density community shrinks from 44% to 14%. If one compares the well-designed high-density community with the report's well-designed low-density community, moreover, the differential narrows to 6%."

Urban Form and Density — People living in cities with high population densities, concentrated employment in the city centre, and extensive transit systems use substantially less gasoline per driver than those residing in low-density communities with dispersed employment. Drivers in New York and Chicago consume less than 10 gallons per week, compared with some 15 gallons consumed per driver in Los Angeles, Tucson, and Houston [3].

A few studies have modelled the future travel requirements associated with alternative urban development options over the past several decades. For example, a study of five regional Year-2000 plans in the Hartford, Connecticut, area, showed that a "balanced" plan would have a work-trip length that is 0.92 times (eight percent less than) in the trend development plan. Corresponding ratios for linear development, satellite cities, and strong-centre plans were 0.96, 0.97, and 1.14, respectively [4].

A study entitled *Energy, Land-Use and Growth Policy: Implications for Metropolitan Washington* (1975) analyzed six alternative 1992 development scenarios in terms of future energy consumption:

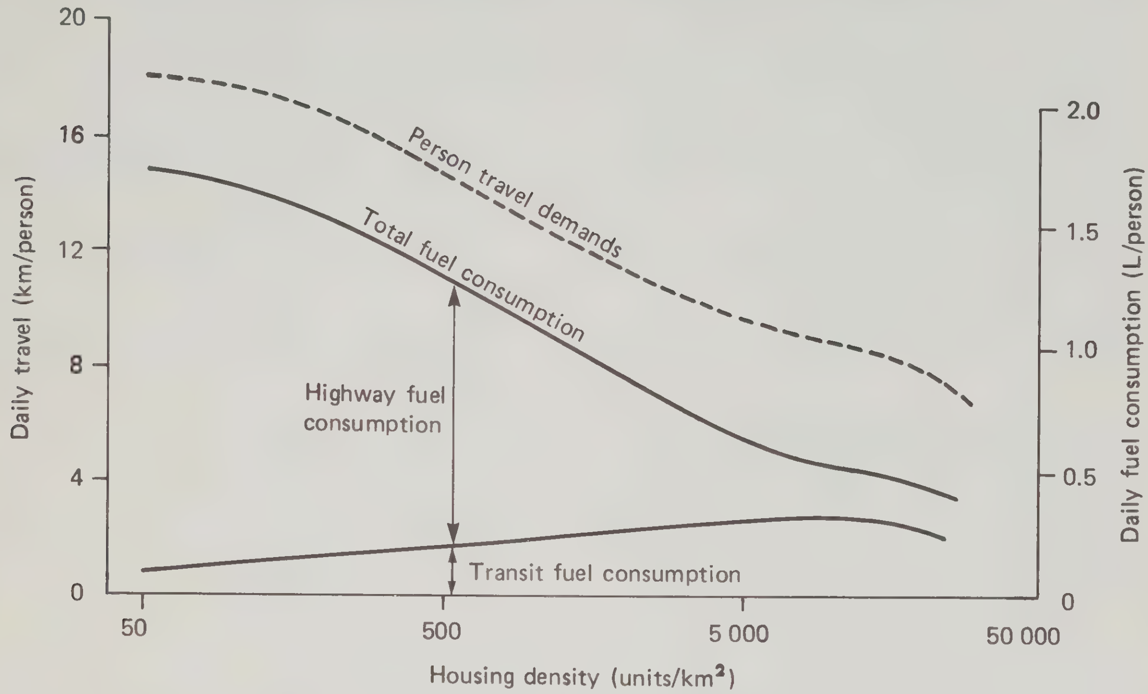
- wedges and corridor,
- dense centre,
- transit-oriented,
- wedges and corridors with income balance,
- sprawl,
- beltway-oriented.

The dense-centre scenario would consume about eight percent less energy in the design year than that with "sprawl" conditions.

Figure 5.2 shows how the person-kilometres of travel in vehicles and the daily litres of fuel used per capita increase in the New York Metropolitan area. These relationships also generally apply in the Metropolitan Toronto and Ottawa areas.

Metropolitan Toronto Energy Study — The *Metropolitan Toronto Area Transportation Energy Study* prepared by Wilbur Smith and Associates for the Metropolitan Toronto Planning Department, the Ministry of Transportation and Communications, and the Toronto Transit Commission,

Figure 5.2
Development Density Versus Weekday Travel and Fuel Consumption



Source: *Improving Mobility.* Tri-State Regional Planning Commission; 1979

found the following relationships between land use and energy consumption [5]:

- Increased transportation and non-transportation energy efficiency can be achieved through *better arrangement of urban activities* by encouraging higher development densities and by reducing single-family construction. These gains could reduce total residential energy consumption by about 50% on a per-dwelling basis, and about 15%-20% on a per-capita basis. They would be accompanied by savings in the commercial sector — since high-density developments would reduce transportation requirements to shopping and work areas and encourage mixed land use, clustering, and building efficiency.
- While it is difficult to model, energy savings might result from *reducing the journey to work* by increasing self-containment of new communities and/or by creating a better balance between employment and population.
- Without any overall increase in gross density, clustering and associated modifications in street layout can *reduce the length of streets and utility installations.* Energy is saved in the construction and, later, in the maintenance of streets, transmission of electricity and water, and provision of services like garbage collection.
- At the community level, *higher density and mixed zoning* can potentially reduce travel distances and make transit more feasible by locating home and work places closer together and by bringing major traffic generators near to each other. Intensifying land use along transportation corridors can encourage the use of public transit, and give people a choice of travel modes.
- *Reducing the per-capita space requirements of new residential construction* would substantially reduce energy consumption over the long run. However, this runs contrary to the common desire to increase living space as income rises.

Six major factors usually determine the energy efficiency of various urban forms [6]. These factors are:

- density,
- geometry,
- orientation to the sun,
- communication and transportation,
- design.

General relationships between development density and energy consumption can be cited.

- Higher residential densities result in lower energy consumption.
- Single-family detached homes consume more energy than low-rise attached, and multi-storey housing.
- In Ontario, space heating in semi-detached houses requires an estimated 25% less energy than in single-family houses, and in row houses, 50% less [7].
- Decreasing exposed surface per enclosed volume minimizes heat transfer. Surface can be

minimized by creating cubical space or by sharing common walls.

- Landscaping and massing of buildings can serve as a shield to wind, sun, or other climatological extremes.
- Increases in residential density may create opportunities to (1) increase efficiency of electromechanical systems through "district" heating, and (2) minimize appliance use by sharing (e.g., washers and dryers).
- Higher-density housing units tend to be smaller than single-family houses, and therefore require less energy for heating and cooling.
- High-density living often means greater public-transport use, and lower auto use.

2.4 Energy-Savings Calculation

Potential energy savings from land-use planning depend upon the size of the areas being considered, the amount of new urban growth and the urban renewal required. Municipal land use plans should:

- provide residential densities and street layouts that can support transit and facilitate transit circulation;
- concentrate new urban development along major transit corridors and around suburban centres;
- increase multi-family residential construction throughout the metropolitan area;
- improve the balance between people and jobs in all parts of the metropolitan area;
- increase the mix and integration of land use;
- provide closer residential developments on smaller lots and in locations where houses can be served by public transport;
- encourage infilling of vacant parcels within the central city and its surrounding suburbs, especially with uses which enhance functional integration;
- encourage mixed-use buildings where large office, shopping, and residential complexes are combined into a single structure. (Examples include Toronto's Eaton Centre, Chicago's Water Tower Place, and Atlanta's Peachtree Center.)

2.4.1 Basic Factors

General guidelines for estimating the effects of development density and building type on energy use are given in Tables 5.1, 5.2, 5.3, and 5.4. These tables can be used as input wherever city-specific data is unavailable.

- Table 5.1 gives trip rates and mode splits for single-family dwellings and apartments. Additional trip rates can be obtained from the *ITE Trip Generation Handbook*.
- Table 5.2 gives annual construction and operating energy for various building types and densities.
- Table 5.3 gives annual energy intensity for residential land uses in Metropolitan Toronto (and Ottawa).

2.4.2 Analysis Approach

Table 5.4 gives annual energy intensity data for areas other than Toronto. In estimating the energy to be consumed by a new development, it is necessary to estimate the type of development, the non-transportation energy consumed, and the likely trip rates, modal shares, and trip lengths. City-specific data should be used, particularly for trip rates and modal shares. Alternatively, Figure 5.3, which is based on the Toronto data, or Table 5.4, which contains estimated values for smaller cities in Ontario, can be used as an approximation.

2.4.3 Analysis Steps

The analysis steps are straightforward. They involve creating data equivalent to that in Tables 5.3 or 5.4, based on city-specific information, or using these tables and then aggregating energy intensity for each type of dwelling, based on the number of units involved.

Step 1. Determine the number of each type of dwelling unit involved.

Step 2. Estimate the trip rates, based on Tables 5.1, 5.3, or 5.4 and the modal split. If transit service is unlikely, assume all trips are by car.

Step 3. Estimate the trip lengths by mode, based on Tables 5.3 and 5.4 or on the results of an origin-destination survey.

Table 5.1
Trip Rates for Single-Family Dwellings and Apartments

Type of dwelling unit	Density (units/net ha)	Average weekday vehicle trip ends/unit	Person-trips/unit at 1.4 persons/car	Assumed car trips (% of total)	Estimated total person-trips/unit
Single-family detached	7.4	10.0	14.0	95	15
Single-family attached	14.8	7.9	11.0	90	12
Low-rise apartment	37.1	5.4	7.5	80	9
High-rise apartment	74.1	3.7	5.2	65	8

SOURCE: *Trip Generation.* An Institute of Transportation Engineers' informational report, Institute of Transportation Engineers, Washington, DC; 1976.

Table 5.2

Annual Construction and Operating Energy for Various Building Types

Structure type	Construction energy (MJ/m2)*	Service life (years)	Annual construction energy (MJ/m2)	Annual operating energy (MJ/m2)	Total annual energy (MJ/m2)
Residential					
Single-family detached	7 960	30	260	1740†	2000
Single-family attached	7 090	30	240	1270†	1510
Low-rise apartment	7 350	40	180	1190†	1370
High-rise apartment	8 350	40	210	1550†	1760
Commercial					
Hotel/motel	12 810	40	320	2000	2320
Office building	18 530	50	370	1900	2270
Garage/service station	8 750	30	290	3210	3500
Store/restaurant	10 580	40	260	2320	2580
Institutional					
Dormitory	15 240	50	300	2000	2300
Religious building	14 270	50	280	2500	2780
Educational building	15 720	50	310	2000	2310
Hospital	19 540	50	390	4530	4920
Industrial					
Industrial plant	11 040	50	220	na‡	na
Warehouse	6 330	30	210	na	na

SOURCE: Wilbur Smith and Associates.

* Source for these figures is U.S. Energy Research and Demonstration; 1967

† Includes 30 MJ/m^2 for delivery of municipal services.

‡ na, not available

Table 5.3

Estimated Energy Intensity of Residential Land Use, Metropolitan Toronto*

	Single-family home			Single-family attached			Low-rise apartment			High-rise apartment		
	Car	Transit	Total	Car	Transit	Total	Car	Transit	Total	Car	Transit	Total
Transport energy												
1. Person-trips (%)	95	5	100	90	10	100	80	20	100	65	35	100
2. Daily urban person-trips unit	14.0	0.7	14 7	11 0	1.0	12.0	7.5	1 5	9.0	5.2	2 8	8.0
3. Average trip length (km)†	10.5	11.3	-	10.5	11 3		10 5	11.3	—	10.5	11.3	.
4. Daily person-km/unit, 2 × 3	147.0	7.9		115.5	11 3	--	78.8	17.0	—	54.6	31.6	—
5. Annual person-km/unit, 4 × 300 days	44 100	2 370		34 650	3 390	-	23 640	5 100	—	16 380	9 480	–
6. MJ/person-km‡	5.9	1 5	--	5.9	1.5	--	5.9	1.5	—	5.9	1.5	—
7. Total annual transport energy, 5 × 6 (MJ/unit)	260 190	3 555	263 745	204 435	5 085	209 520	139 476	7 650	147 126	96 642	14 220	119 862
Non-transport energy												
8. MJ/m2			2 000			1 510			1 370			1 760
9. m2/unit			120			110			100			60
10. Total annual non-transport energy, 8 × 9 (MJ/unit)			240 000			166 100			137 000			105 600
Total annual energy, 7 + 10 (MJ/unit)			503 745			375 620			284 126			216 462

SOURCE: Levinson, H S , and H E Strate *Land Use and Energy Intensity* Presented at the Transportation Research Board Annual Meeting, Washington, DC; January 1981

*Data will also apply to Ottawa

†TARMS, 1971

‡Estimated from various sources

Step 4. Estimate the person-kilometres by mode (Step 2 x Step 3).

Step 5. Estimate the annual person-kilometres by mode (Step 4 x 300 days).

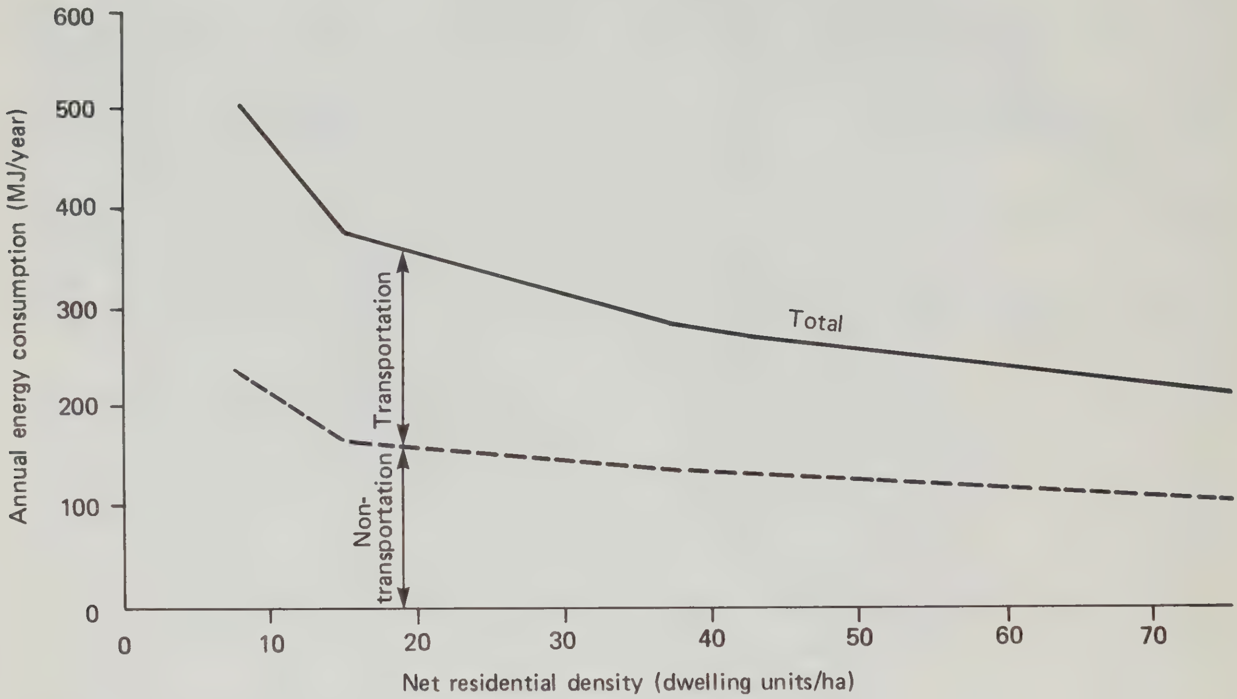
Step 6. Estimate the megajoules per person-kilometre (use 5.9 for car, 1.5 for transit, in Toronto and Ottawa).

Step 7. Multiply the annual person-kilometres by mode (Step 5 x the energy-intensity factors in Step 6) to obtain the transportation energy used per unit, by mode. Add the auto and transit components to obtain the total.

Step 8. Add the non-transportation energy to the transportation energy by unit type.
240 000 MJ/unit — single family home
166 100 MJ/unit — single family attached
137 000 MJ/unit — low-rise apartment
105 600 MJ/unit — high-rise apartment

Figure 5.3

Estimated Effect of Residential Density on Energy Consumption, Toronto 1979



Source: *Metropolitan Toronto Area Transportation Energy Study.* February 1981.

Table 5.4

Estimated Energy Intensity of Residential Land Use, Communities other than Toronto and Ottawa

	Single-family home			Single-family attached			Low-rise apartment			High-rise apartment		
	Car	Transit	Total	Car	Transit	Total	Car	Transit	Total	Car	Transit	Total
Transport energy												
1. Person-trips (%)	97	3	100	94	6	100	90	10	100	85	15	100
2. Daily urban person-trips/unit	14.5	0.5	15.0	11.3	0.7	12.0	8.1	0.9	9.0	6.8	1.2	8.0
3. Average trip length (km)*	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
4. Daily person-km/unit, 2 × 3	87.0	3.0	90 0	67.8	4.2	72.0	48.6	5.4	54.0	40.8	7.2	48.0
5. Annual person-km/unit, 4 × 300 days	26 100	900	27 000	20 340	1 260	21 600	14 580	1 620	16 200	12 240	2 160	14 400
6. MJ/person-km†	5.9	1.0	—	5.9	1.0	—	5.9	1.0	—	5.9	1.0	—
7. Total annual transport energy, 5 × 6 (MJ/unit)	153 990	900	154 890	120 006	1 260	121 266	86 022	1 620	87 642	72 216	2 160	74 376
Non-transport energy												
8. MJ/m2			2 000			1 510			1 370			1 760
9. m2/unit			120			110			100			60
10. Total annual non-transport energy, 8 × 9 (MJ/unit)			240 000			166 100			137 000			105 600
Total annual energy, 7 + 10 (MJ/unit)			394 890			287 366			224 642			179 976

SOURCE: Adapted by MTC from Table 5.3 (Levinson and Strate).
*Typical value (will vary with city size).
†Estimated at 67% of the value for Toronto (Table 5.3). Transit energy will vary with city size.

Step 9. Weight — Multiply the energy for each type of unit by the number of dwelling units of that type.

Table 5.5 is a detailed worksheet based on these steps. Table 5.6 provides a simplified worksheet for use with the output of Table 5.5, and gives an illustrative problem and its solution. (See Appendix for blank worksheets.)

Note: Land-use planning to conserve energy will be most immediately effective in rapidly growing communities. It may be less effective in areas where population has stabilized and little growth is expected, as the gains will be slower to materialize.

Table 5.5

Land-Use Planning — Example Using Detailed Worksheet

1. Describe proposal

Single-family homes			1000 units
Single-family attached			500 units
Low-rise apartments			200 units
High-rise apartments			100 units

2. Estimate person-trips by type of unit. The form shown here is for one type of unit; use a separate form for each type.

	Auto	Transit	Total
% person-trips by mode	97	3	
Number of daily urban person-trips/unit	14.5	0.5	
3. Estimate average trip length (km)	6.0	6.0	
4. Estimate daily person-km/unit, 2 × 3	87.0	3.0	
5. Estimate annual person-km/unit, 4 × 300 days	26 100	900	
6. Estimate modal energy intensity (MJ/person-km)	5.9	1.0	
7. Estimate annual transport energy, 5 × 6 (MJ/unit)	153 990	900	154 890
8. Estimate total building construction and maintenance energy (MJ/unit)			240 000
9. Obtain total energy, 7 + 8 (MJ/unit)			394 890
10. Weight by number of units, 1 × 9 (MJ)			394.9×10^6

Table 5.6

Land-Use Planning — Example Using Simplified Worksheet

1. Describe proposal

Single-family homes	1000	units
Single-family attached	500	units
Low-rise apartments	200	units
High-rise apartments	100	units
Location	Windsor	

2. Estimate annual energy intensity by unit type (from the bottom line of Table 5.3 for Toronto and Ottawa or Table 5.4 for other cities)

Single-family homes	394 890	MJ/unit
Single-family attached	287 366	MJ/unit
Low-rise apartments	224 642	MJ/unit
High-rise apartments	179 976	MJ/unit

3. Obtain total annual energy by multiplying energy per unit by the number of units of each type

Single-family homes	394.9×10^6	MJ
Single-family attached	143.7×10^6	MJ
Low-rise apartments	44.9×10^6	MJ
High-rise apartments	18.0×10^6	MJ
Total annual energy	601.5×10^6	MJ

3 Alternative Work Schedules

3.1 Strategy and Objectives

Alternative work schedules are a means of spreading transportation demand over different time periods, thereby reducing travel demand and enhancing the operational efficiency of the street system during the peak hours. The energy savings are the result of the reduction in travel, congestion, and delay. Stop-and-go driving consumes energy at a higher rate than smooth-flowing traffic. By spreading transit demand over more hours, the efficiency of the transit system is also improved.

Variable work-hours within a day do not change overall travel demand; reduced congestion is the main objective and source of energy conservation. Compressed work-weeks also tend to shift travel from peak hours, but, in addition, will reduce total travel demand by requiring fewer trips over a one-week period.

Alternative work schedule programs relate to changes in travel between home and work. There is evidence that, as a result of alternative work schedules, some additional travel occurs for non-work trip purposes, particularly for recreational activities on the newly created off-day.

Peak-hour travel reductions as a result of variable work hours may tend to build up again as a result of increased activity in the employment zone. However, this should still be a net energy reduction, since these new trips may otherwise have been generated in zones requiring longer trips and with lower transit-service availability.

3.2 Description of Measures

3.2.1 Staggered Work-Hours

These are programs which implement specific work-hours for groups of employees, spreading the beginning and ending times over a one- or two-hour period. Groups arrive and leave 15 to 30 minutes apart.

Staggered work-hour programs spread auto traffic loading but may have some detrimental effect on ridesharing and transit service by offsetting employee beginning and ending work-times. Such programs reduce the population for matching of partners for ridesharing. Transit service may also be more difficult to schedule, especially where equipment availability is critical and load factors are low. However, where transit demand is high, spreading of the peak hour can help transit operations.

3.2.2 Flexible Work-Hours (Flex-Time)

These are programs in which working hours are selected at the individual discretion of the employee, provided specific core hours are included.

Flexible work-hours will spread peak loading almost as well as staggered hours, but this program can also encourage ridesharing. Individuals will have greater opportunity to arrange their work-hours and make match-ups for car- and vanpools.

3.2.3 Shortened Work-Weeks

Like staggered work-hours, these are specific schedules established for employees. In a shortened work-week, employees compress their work-hours into four days and thus have one additional day off.

The four-day work-week refers to a schedule of 9 to 10 hours of work, four days a week, or some similar arrangement, which permits a full work-week and at least one weekday for leisure. While this measure is expected to reduce the work trip by one day a week, additional fuel consumption could result from increased leisure travel. Problems similar to those associated with staggered work-hours may be encountered in implementing the four-day work-week in conjunction with car-pooling.

3.3 Effectiveness of Measures

A quarter to a half of all employees in a localized employment area can be expected to become involved in a variable-work-hour program if a dominant employer or an important employer or employee organization takes the initiative. The trip-timing decisions employees make when given the option of flexible work-hours are as effective as mandatory staggered work-hours in spreading out work-arrival and -departure times. A large-scale program can smooth traffic peaks enough to reduce maximum 15-minute passenger and vehicular loads by 15%-35% at terminal facilities such as rapid-transit stations and major parking lots.

Variable-work-hour-program effects become diluted on the outer portions of radial transportation facilities serving the involved employment core. Even so, the impact may remain quite significant, particularly on transportation system elements such as radial bus routes. Maximum 15-minute bus-passenger load reductions as great as 21%-29% have been reported. The transportation system elements offering the least potential for peak-period volume modification are those used heavily by traffic from diverse locations.

Most findings from actual program applications contradict any supposition of potential shifts to single-occupant-auto use in response to variable work-hours, or of possible increases in total household travel in response to compressed work-weeks. In the case of flexible-work-hour programs, there is evidence that carpooling may be facilitated and increased, as would logically be inferred. First-year results for the Denver federal-employee-compressed-work-week experiment show decreases in household vehicle-kilometres of travel for both work and non-work travel, with a 14% reduction overall for participating agency households, relative to those of other agencies.

Employee attitudes toward staggered and flexible work-hours are generally positive, with 80%-95% of workers involved expressing a favourable overall reaction. The employee reaction to compressed-work-week programs is mixed, but appears to be favourable in current federal-worker programs. Most employers report increased or unchanged efficiency, on balance, under staggered- and flexible-work-hour programs [8].

Reported changes in modal choice after work-schedule changes vary widely. There is some evidence that more flexible work-hours will encourage ridesharing, since individuals will have greater opportunity to arrange their work-hours and make matches. Five percent more employees used transit and six percent more shared rides after flex-time was introduced at the Transportation Systems Center in Cambridge, Massachusetts. The Ottawa Variable Work Hours program showed no consistent changes in auto occupancy, while transit's share of peak-period travel to the central area increased by five percent.

Variable work-hours may shorten highway travel time by reducing congestion. Estimates based on Denver and San Francisco traffic conditions suggest a 0.6%-1.2% decrease in travel time for each 1% reduction in peak-hour travel time. Examples of travel-time estimates are as follows .

Location	Travel category	Travel-time reduction (min) One-way	Travel-time reduction (min) Round trip
Toronto	Participants only	3	
Riverside CA	All employees	2.5	
Washington, DC	Participants only		8

Location	Travel-time reduction (min): Participating agencies, Participants	Participating agencies, Non-participants	Non-participating agencies, all employees
CBD	5.3	0.6	2.2
Non-CBD	0.8	1.6	−0.5*

*Increased travel time.

Participation	Travel-time reduction (min) Peak hour	Peak period
50% CBD	3.75	2
20% CBD	1.5	0.8

Surface transit vehicles may be expected to save about half as much travel time as autos, except in express operations, where the savings should be equivalent. However, transit-rider benefits mainly involve avoiding uncomfortable crowding and vehicles too full to board. Participants in Lower Manhattan saved an average of 3.5 minutes each morning merely by avoiding the period of maximum train annulments and delays.

Staggered- and flexible-work-hour programs, with no change in the work-week, depend on lessened traffic congestion for energy savings and emission reductions. Travel-time-reduction estimates modelled for a hypothetical city of 1 000 000 for a typical CBD employee are as follows:

	Peak Hour	*Peak Period*
50% CBD Participation	3.75 min	2 min
20% CBD Participation	1.5 min	0.8 min

The Ottawa variable-work-hour program, which involved roughly half of all CBD employees, was used as a travel-impact data source. The calculated vehicle-time saving for the extensive, 50%-CBD-worker-participation scenario was 600 000 vehicle-hours annually. Assuming no change in regional vehicle-kilometres travelled (VKT) this reduced congestion results in a reduction of about 1 600 000 litres annually, about 0.11% of the regional auto fuel consumption.

Unlike other variable-work-hour programs, the compressed work-week reduces the actual number of individual worker commuting trips. It has the potential to reduce commuting VKT by 20% for 4-day-work-week participants if there are no significant mode shifts. The potential for net overall VKT reduction will be reduced to the extent that

increased non-work travel is induced on days off. In theory, the possibility exists for total household VKT actually to increase because of increased recreational travel.

Concerns about possible total VKT increases are *not* supported by first-year Denver and first-quarter FHWA/Washington results of federal-employee compressed-work-week experiments. In Denver, where roughly half of the individual participants are on 4-day work-weeks, total family VKT for participating agencies was reduced by 14%, relative to control groups. This reduction was spread across all 7 days of the week.

This 14% relative VKT reduction for participating agencies works out to a 5% reduction for all Denver federal employees and a 0.3% reduction relative to total region-wide travel. The corresponding reductions calculated for energy use and air-pollutant emissions are virtually the same, with the energy savings equal to 4 500 000 litres per year. Actual improvements in air quality obviously vary by time and location; 38% of the total emissions reduction pertains to weekend travel[9].

Assuming a range of 15%-70% of the work force on a four-day work-week and no additional recreational travel, it is estimated that energy consumption could be reduced by 1.25% to 6.5%.

3.4 Implementation Experience

Table 5.7 summarizes the penetration and impact of work-rescheduling programs in several cities. Programs implemented in Toronto achieved the involvement of about one quarter of the Central Business District employment, while programs implemented in Ottawa encompassed nearly 50% of CBD employment.

In Toronto, the program which started in October 1973, involving 11 000 public employees of the city's Queens Park Complex, was effective in distributing the demand for transportation facilities over a long period of time. One-third of the employees experienced a decrease in travel time as a result, and approximately one-third felt that their trip was more comfortable and convenient. Generally, over 90% of the employees involved expressed a favourable reaction to this demonstration program. Furthermore, the Ontario Ministry of Transportation and Communications, in its final evaluation of the demonstration in 1975, considered the program a success and recommended that it be continued and extended to all public employees in the Queens Park area.

In Ottawa, impacts on total transit loads and auto volumes in the CBD are substantial, but outside the CBD boundaries they are reduced as a result of the presence of other traffic. Table 5.8 and Figure 5.4 illustrate this dilution effect, showing reductions in peak-hour percentages for different modes and locations. The results in this table show that when 50% of the workers are participating, transit-terminal arrival/departure percentages are reduced by 20%.

- Peak-hour arrivals at parking lots in a CBD are reduced by approximately 17%.
- Peak-hour auto volumes at CBD core screenlines are reduced by 10%.
- Peak-hour auto volumes on an important radial-route bridge near the CBD are reduced by 5%.
- Peak-hour bus passenger loads at the CBD core screenline are reduced by 14%.

These impacts are considered to be reasonably representative of the maximum potential impact on peak work volumes of a variable-work-hour program, since nearly 50% of the Ottawa CBD employees were participating in the program.

Between 73% and 75% of employees involved in flex-time studies in San Francisco and the Port

Table 5.7

Penetration of Comprehensive Variable Work Hours Programs

Urban area	Estimated total employment	Estimated CBD employment	Employees in formal work hours program		
			Number	% of total	% of CBD
New York, NY	7 500 000	2 000 000	220 000	3	11
Philadelphia	1 800 000	300 000	43 000	2	14
Toronto	1 000 000	260 000	68 000*	7	26
Washington, DC	1 200 000	500 000	200 000	17	40
Madison, WI	122 000	17 000	5 000	4	29
Riverside, CA	50 000	n.a.†	3 200	6	n.a.
Ottawa	200 000‡	70 000	33 000	17	47
Average				8	28

Source: Keyani, B.I., and E.S. Putnam. *Transportation System Management — State of the Art.* Office of Policy and Program Development, U.M.T.A.: Washington, DC; February 1977.

* Plus 29 000 potential.

† n.a., not available.

‡ Estimated.

Authority of New York and New Jersey reported work-arrival and -departure times designed to avoid traffic and transit congestion. (Figure 5.5 shows data for several office buildings in San Francisco.)

The effects of flexible hours on car and transit trips in central Ottawa are shown in Figures 5.6 and 5.7. The peak 15-minute transit volume in 1976 was 27% less than that in 1974 before Ottawa's program was initiated; similarly, the peak 15-minute auto volume was reduced by 18%.

Table 5.8

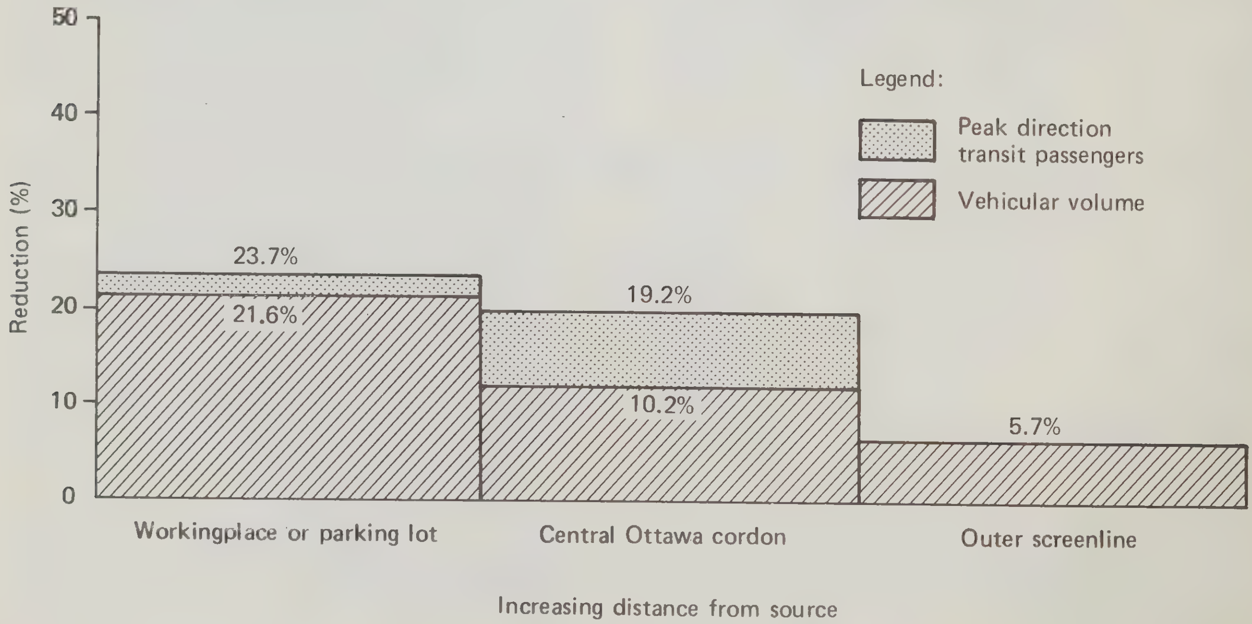
Summary of Estimated Impacts of Work Rescheduling Strategy, Ottawa

Mode and location sampled	a.m. peak, 2.5 h Before (% at peak hour)	After (% at peak hour)	% reduction	p.m. peak, 3 h Before (% at peak hour)	After (% at peak hour)	% reduction	Average % reduction (a.m. and p.m.)
Government-employee transit users at workplace	86.2	71.6	16.9	85.3	65.1	23.7	20
Autos at parking lots	62.1	53.7	13.5	57.3	44.9	21.6	17
Bus passengers at CBD cordon	67.9	62.2	8.4	62.0	50.1	19.2	14
Autos crossing CBD cordon	55.0	49.2	10.5	46.3	41.6	10.2	10
Autos crossing river-crossing cordon	53.0	51.6	2.6	45.7	43.1	5.7	4

SOURCE: *Traveler Response to Transportation System Changes*. Federal Highway Administration, U.S. DOT: Washington, DC; February 1977. p. 110.
Note: Approximately 50% employee participation.

Figure 5.4

Reductions in p.m. Peak Volumes for Different Modes and Locations



Note: The Ottawa variable work hours program involved a single dominant employer, the Canadian Federal Government.

Figure 5.5

Distribution of Workplace Arrival Times, San Francisco

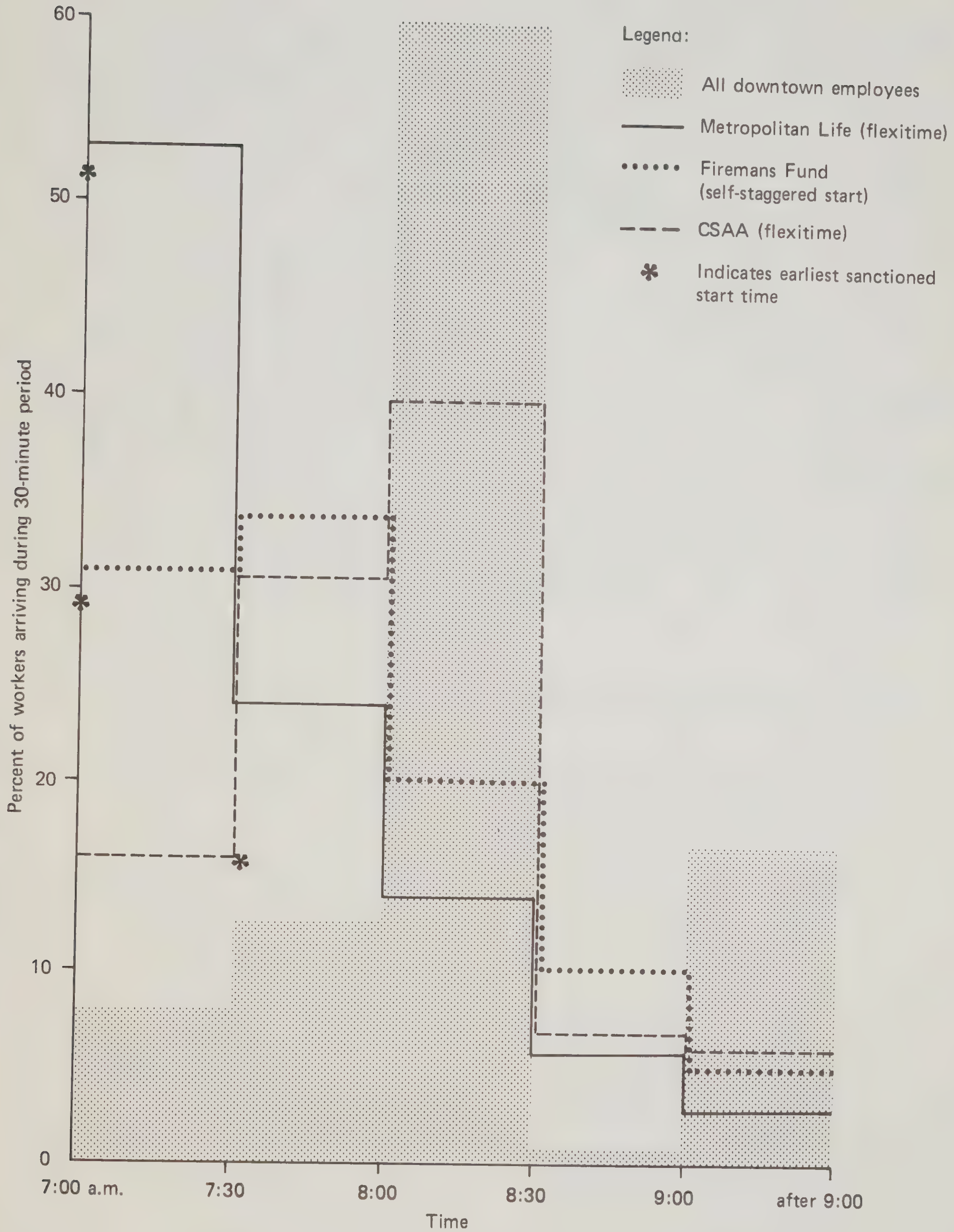
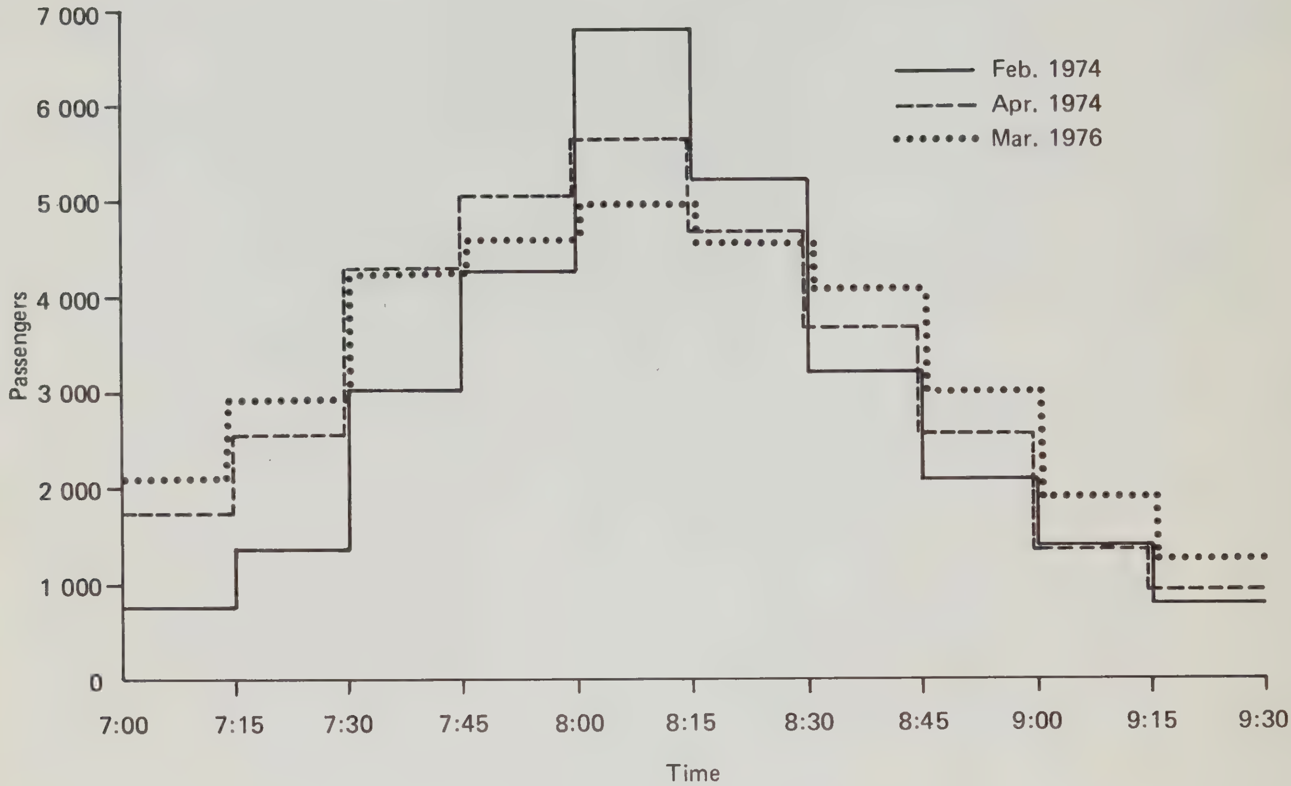
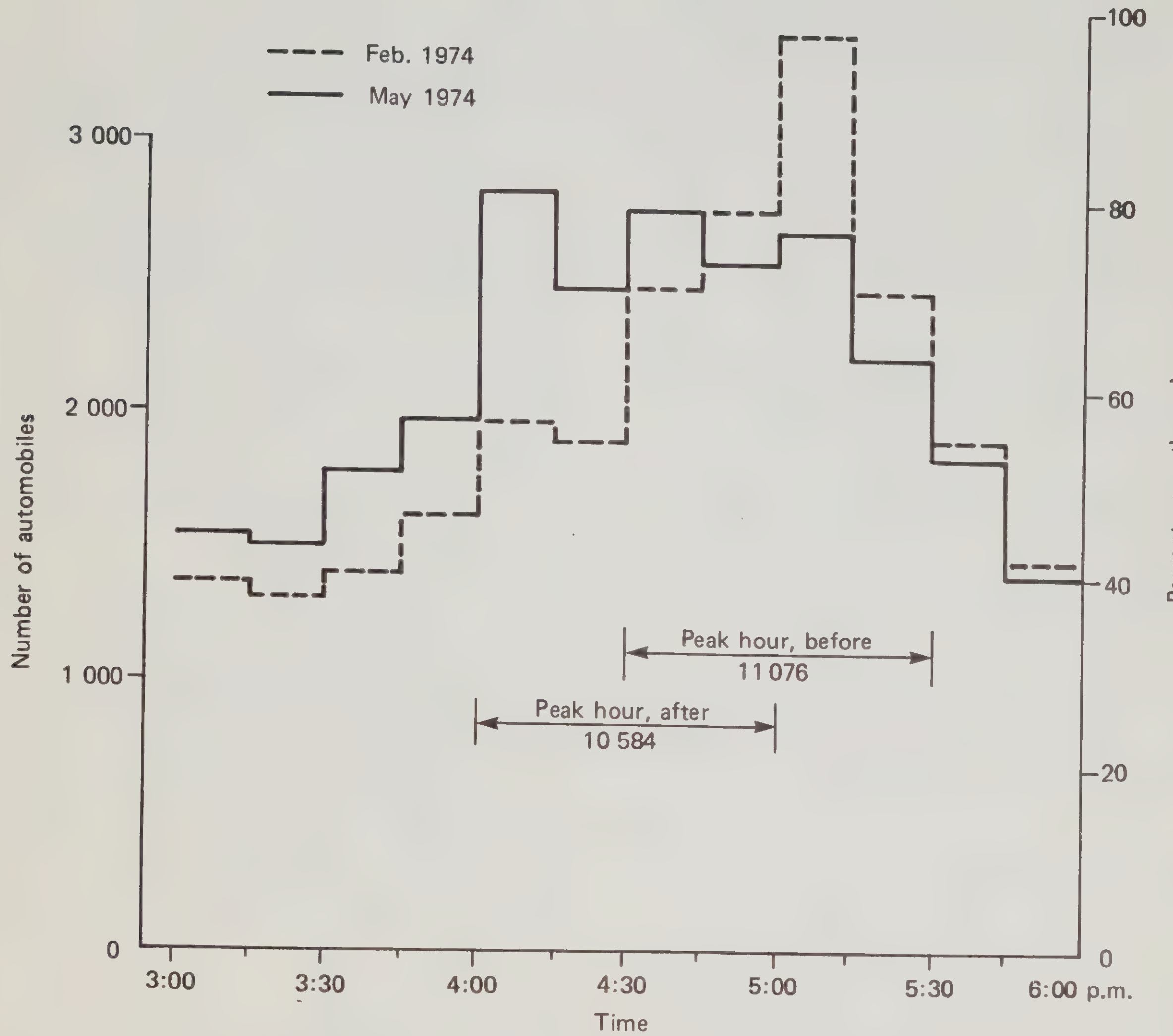


Figure 5.6
Effect of Flexible Hours on Transit Usage Across CBD Screenline



SOURCE: Bonsall, et al. *Case Study on Ottawa-Carleton*. February 1979.
Note: Flexible hours were introduced on 4 March 1974.

Figure 5.7
Effect of Flexible Hours on Auto Usage Across CBD Screenline



SOURCE: Bonsall, et al. *Case Study on Ottawa- Carleton.* February 1979.
Note: Flexible hours were introduced on 4 March 1974.

3.5 Energy-Consumption Calculations

Potential energy savings from work-schedule changes will depend upon (1) the degree of peak-hour road congestion and (2) the number of employees participating in the program. The energy implications are realized through possible reductions in travel times and vehicle-kilometres of travel. Where compressed work-weeks are being considered, it is necessary to consider some added discretionary travel by the car and people left at home.

3.5.1 Analysis Approach

This method of assessing energy savings requires information on program penetration, travel patterns, peak and off-peak auto speeds, and possible changes in modal use. A *conservative* estimate of energy savings can be obtained by merely analyzing the VKT and speed changes of the target employees. This does not consider any fuel savings resulting from faster travel speeds on other work-trips.

Key data inputs are:

- population of the study area;

- number of target employees in the area being considered — those that participate and those that do not;
- place-of-residence or trip-length distributions of target employees — leading to an average trip length;
- average peak-period speed before any program is established;
- average off-peak speeds;
- current travel modes and car occupancies for target group;
- fuel consumption in litres per 100 km for constant speeds;
- adjustment changes for factors in fuel economy by year.

It is also necessary to assume 250 working days each year, or 500 work-trips per employee for programs involving work-schedule changes, and 400 trips for the compressed work-week.

The procedure calls for estimating: (1) the gasoline consumption of the target group *before* implementation of any action; and (2) gasoline consumption of the participating and non-participating employees *after* an action has been put into effect. The net energy fuel savings can then be obtained.

The simplest approach is to assume no changes in car occupancy or modal choice. Alternatively, allowance for these changes can be introduced, based on specific local experience.

3.5.2 Analysis Steps

The analysis calls for 5 basic steps:

Step 1. Estimate the existing annual fuel consumption for the target population (see Formula 1, below).

Step 2. Estimate the annual fuel consumption for the target population participating in the program (see Formula 2 for staggered work-hours and flex-time, and Formula 4 for compressed work-week).

Step 3. Estimate the annual fuel consumption for the target population *not* participating in the program (see Formula 3 for staggered work-hours and flex-time, and Formula 5 for compressed work-week).

Step 4. Calculate the difference between Step 1 and the sum of Steps 2 and 3. This represents the estimated annual fuel savings.

Step 5. Adjust this savings by the appropriate annual adjustment factor to compensate for changes in fuel economy. This will yield the annual adjusted savings.

The formulae for analyzing staggered-hour and flex-time energy savings are as follows:

Before:

1. $G_1 = E \cdot p_1 \cdot L\ 500\ g_1$

Where:

E = *target employment*
p_1 = *proportion of employment travelling as car drivers,* ***before***
L = *trip length in kilometres (obtain from surveys, interviews — about 11 in Toronto and 6 in smaller areas).*
g_1 = *litres/kilometre corresponding to operating speed on street during peak hours*
G_1 = *ANNUAL LITRES BEFORE - TOTAL*

After:

2. $G_2 = E \cdot p_2 \cdot X \cdot L\ 500\ g_2$ *(Participants)*
3. $G_3 = E \cdot p_2 \cdot (1\text{-}X) \cdot L\ 500\ g_3$ *(Others)*

Where:

L = *trip length in kilometres (obtain from surveys, interviews — about 11 in Toronto and 6 in smaller areas).*
E = *target employment*
p_2 = *proportion of employment travelling as car drivers* ***after*** *(1 may be equal to p_1)*
g_2 = *litres/kilometre corresponding to operating speed during staggered hours*
X = *proportion of participating employees*
g_3 = *litres/kilometre corresponding to operating speed during peak hours (may be equal to* ***before*** *condition)*
G_2 = *ANNUAL LITRES AFTER - PARTICIPANTS*
G_3 = *ANNUAL LITRES AFTER - OTHERS*

The formulae for analyzing compressed work-weeks are as follows:

Before:

Formula 1 (as above)
After:

4. $G_2 = E \cdot p_2 \cdot X \cdot L\ 400 \cdot g_2 \cdot R$ *(Participants)*
   $G_3 = E \cdot p_2 (1\text{-}X) \cdot L\ 500 \cdot g_3$ *(Others)*

Where:
R = *"estimated additional use of second car" factor*
$1 < R < 1.25$ *(say 1.12)*

Table 5.9 gives a simplified worksheet based on these steps and formulae, with a sample problem and its solution. See Appendix for blank worksheet for applying these formulae.

Table 5.9

Impact of Work Schedule Changes — Sample Calculation for Compressed Work Week

	Before change (A)	After change		Difference A − (B + C)
		Participants (B)	Others (C)	
1. Total target workers	3000	1000	2000	
2. % car drivers	70	70	70	
3. Number of car drivers, 1 × 2	2100	700	1400	
4. Trip length (km)	6.4	6.4	6.4	
5. Daily VKT, 3 × 4 × 2 trips/day	26 880	8 960	17 920	
6. Annual VKT, 5 × 250 days*	6 720 000	1 792 000*	4 480 000	448 000
7. Adjustment for car use at home†	1.0	1.12	1.0	
8. Adjusted annual VKT, 6 × 7	6 720 000	2 007 040	4 480 000	232 960
9. Speed (km/h)	29.4	45.5	29.4	
10. Fuel consumption (L/km) at above speed	0.127	0.104	0.127	
11. Annual fuel consumption, 8 × 10 (L)	853 440	208 732	568 960	75 748

* 5 × 200 days for compressed work week.

† Adjustment factor is 1.0 except for compressed work week when it is 1.12.

3.6 Implementation Procedure

Use of variable work schedules as a method of reducing fuel consumption should be considered by following this sequence of steps:

- Identify large employment centres with more than 750 employees.
- Identify area(s) of the street system where congestion is a problem.
- Select potential program for variable work schedule.
- Estimate reduction in peak-hour VKT, and the benefit this would have on travel speeds. Estimate reduced travel demand over a one-week period.
- Calculate energy savings, using travel-time-in-system formula and reduction in total travel per day.
- Select programs to be recommended. Approach major employers to discuss implementation.

4 Parking Management

4.1 Strategy and Objectives

The availability and operation of parking facilities can have a dramatic effect on traffic demand and fuel consumption. Adding new off-street parking space can make roadway space available and thus increase traffic speed and flow and, in general, reduce vehicle-hours of travel. Parking-space reductions can lead to reduced numbers of auto trips to an area, thus speeding up traffic on the street and reducing both vehicle-kilometres and vehicle-hours of travel.

Parking restrictions may reduce the number of trips made to one area, but shifts of trip destination may lead to increases in traffic in other areas. Ideally, transit should be available to substitute for the auto trips that are discouraged.

Parking management requires decisions on:
- location of parking;
- amount of on-street and off-street parking;
- parking charges or rates;
- length of time parking is permitted.

In general, parking management programs require:
- fast, dependable, convenient, and reasonably priced alternative means of transportation (i.e., bus, subway, carpool);
- ability to impose substantial price changes (price elasticities for parking are low — 0·15 to 0·30);

From an energy perspective, parking management programs are intended to increase the general cost of using a single-occupant car, in order to encourage a mode shift to transit or other high-occupancy vehicles.

Also, if a sufficient supply of off-street parking exists, the on-street controls may have little effect in encouraging transit use. Parking permit programs, either in the activity centres or in surrounding residential neighbourhoods, may be another effective parking-control measure.

Parking management actions are most applicable in the city centres, outlying commercial centres, and high-density residential neighbourhoods. Transit availability is essential where parking-management actions call for constraining supply or price. Commuter parking lots adjacent to transit terminal stations are particularly effective in encouraging transit use.

4.2 Description of Measures

4.2.1 Parking Rates

Increased or differential parking rates add to the cost of driving a car into a given area, especially for work trips. This increase must be sufficient to cause a switch to transit or to ridesharing. Energy is then conserved through reduction of vehicle-kilometres of travel.

Several conditions of applicability must be present for this measure to be effective:
- availability of an alternative transportation mode (e.g., transit, carpool);
- substantial change in parking fee;
- control of all or most of the parking in the area.

Table 5.10 summarizes the types of cost actions that can be considered in a parking-management program.

4.2.2 Parking Supply

Greater use of transit or high-occupancy vehicles can be fostered by limiting the supply of parking spaces. A further supply strategy is to limit some of the existing spaces to use by car- or vanpools.

Table 5.11 summarizes the parking-supply-management actions. These include upper limits on parking space requirements, ceilings on total CBD parking supply, reduced minimum parking requirements, and carpool/vanpool preferential parking allocation.

Residential Parking Permits — Residential-parking-permit programs are designed to reduce the parking demand from people not living in a particular neighbourhood but parking their vehicle there for various purposes. This method prevents long-term parking by commuters in residential neighbourhoods. Permits are sold by the municipality, to residents only, for fees ranging from \$5-\$10. Communities that have implemented residential-parking-permit programs have been generally satisfied by their success in alleviating local parking problems.

4.3 Effectiveness of Measures

Parking programs in the downtown area of a large city are usually designed to encourage transit use, while simultaneously maintaining car access for

Table 5.10

Parking Management Cost Actions

Element	Summary	Impacts
Parking surcharge	Flat fee levied on use of parking space Deters short term usage if always in effect Can be applied during a.m. peak only	No reported impacts Estimated impact is 1.5 – 6.5% decrease in CBD work trips (0.2–0.4% of regional work trips)
Rate increases	Lump-sum surcharges have more psychological impact than incremental price hikes in discouraging auto use Could increase rates for nonHOVs and hold rate for HOVs	No reported impacts Impacts could be similar to parking surcharge
Rate regulation	Local government to set rates for all commercial and municipal facilities	No reported impacts Impacts could be similar to parking surcharge
Extension of commercial rates to private facilities	Impose a charge on drivers who do not now pay for parking (estimated at 93% of all auto drivers) Problem to induce owners to charge employees and customers No program has been implemented but may be in Washington for government employees	Estimated impact of a 50¢ charge by public institutions for employee parking in Denver is a 0.05% decrease in areawide vehicle travel Estimated impact of commercial rates for private parking in Washington is a 15% (considered an over-estimate) decrease in CBD work-trip vehicle travel
Rate adjustments to discourage long-term use	Progressive rate schedule with increasing costs per hour or Hourly flat rate and no daily maximum	In area of excess demand in Philadelphia a 20% decrease in long-term and 26% increase in short-term use In area of excess supply in Philadelphia a 13% increase in long-term and a 15% increase in short-term use Denver estimated a negligible change in total vehicle travel because the decrease in work-trip vehicle travel offset the increase in nonwork-trip vehicle travel
Rate differentiation by vehicle occupancy, size, performance	Discount rates for carpools Discount rates for small cars See also Rate increases	In Toronto the negligible effect of reduced rates for carpools was attributed to location of lots selected In Seattle reduced or eliminated charges in two facilities (one lot, one garage) increased carpooling but partly at the expense of transit ridership
Direct subsidy to HOV users	Increases perceived cost of driving alone	No impacts reported
Property assessment	Could be based on potential land use rather than existing land use for open lots or when more than the legislated minimum amount of parking is provided	No impacts reported
Transferable parking permit	Reduce cost for poolers Poolers could be given preference for permits	No impacts reported

Table 5.11

Parking Management Supply Actions

Element	Summary	Impacts
Moratorium on construction of new parking	Policy to freeze parking supply	No reported impacts Denver estimated an areawide reduction of 3.2% in vehicle travel
Prohibition of on-street parking	Straightforward restraint on parking supply Generally used for traffic operations reasons	Reduced congestion and emissions No reported impacts on reduction in vehicle travel If done on a large scale there may be proliferation of travel and complementary disincentives directed at nonHOVs may be required
Acquisition and elimination of parking facilities	Very costly method to influence supply	No reported impacts
Constraining new growth in parking supply	Alternative to moratorium on construction Done through zoning codes and plan reviews Reduce or eliminate space requirements for new buildings Set maximum space allowance for new buildings Exchange parking reduction for HOV encouragement by developer Substitute on-site parking for spaces in park-and-ride lot	No reported impacts yet, but some programs started Denver estimated a 0.7% reduction in areawide vehicle travel for a maximum of 0.5 single occupant spaces per employee at public institutions and a 1.9% reduction for large employers
Provide fringe or mode interchange parking	Popular strategy Carpool lots on Ontario freeways Establish lots at transit stations and along express bus routes	Generally done in conjunction with transit improvements Individual impacts not reported
Area permit programs	Used at universities or other private facilities Recently used in residential areas close to commercial or office development to ban or limit stay of nonresidents Enforcement is absolutely necessary	No data on effectiveness of reducing vehicle travel through residential permits Portland has a carpool permit program for all-day on-street spaces which has eliminated 35 cars but negligible effect on vehicle travel
Priority parking for carpools	Designate most convenient space for pools Generally done in private lots	Many examples but none by municipalities for public parking Denver estimated a 0.15% reduction in vehicle travel for preferential parking at public institutions and 0.40% for large employers
Exclusive facility for carpools	Only carpools allowed in some well located public parking lots	No reported impacts
Regulate hours of operation	Prohibition of on-street parking during some hours is common Municipal lots could open only after the a.m. peak May only be effective when done in conjunction with constraint in growth of parking supply	No reported impacts on vehicle travel Denver estimated an areawide vehicle travel reduction of 0.5% if all commercial facilities were limited to 50% occupancy before 10:00 a.m. (0.16% decrease for 60% occupancy)
Restrict time of occupancy	Common with on-street or metered off-street parking Intended to increase turnover	No reported impacts on vehicle travel
Improved enforcement	Use of illegal spaces effectively increases supply In Boston 27% of all vehicles used illegal spaces In Washington 57% of all meter usage was illegal (expired or beyond maximum time limit)	No reported impacts

Table 5.11 (continued)

Element	Summary	Impacts
	More funds required to improve enforcement	
Supply constraints	Any of the above which effectively adds time to the present CBD walk time	Denver model estimated an additional 5-min walk would result in a 0.1% reduction in areawide work-trip vehicle travel and a 0.2% reduction for a 10-min increase

Table 5.12

Selected Parking Management Pricing Tactics and Impacts

Jurisdiction	Description of pricing tactic	Impact
Honolulu, HI	Municipal parking rates increased from 20¢ to 40¢/h in high demand areas and from 15–20¢ to 25¢/h in fringe to discourage long-term parking	Number of cars parked between 7 a.m. and 3 p.m. increased from 4645 to 4847 off-street and from 6265 to 6735 on-street Number of available spaces at lunch hour increased from 209 to 495 off-street and from 260 to 440 on-street Total revenue per month increased by $49 000 (36%)
Montgomery County, MD	Municipal parking rates increased from 10¢ to 25¢/h at most facilities Rates at selected off-street facilities kept at 10¢/h to encourage use of underutilized facilities Carpool permits sold at $16/month versus standard permit of $24/month (also reserved carpool spaces) Merchant parking-validation program is in effect	Average turnover in short-term spaces increased from 3.39 to 3.78 vehicles/space Shift of parkers to underutilized facilities did not work Carpool spaces 74% occupied
Portland, OR	Short-term parking 60¢/h on straight line basis Merchant parking-validation program is in effect Carpool permit $15/month	288 car pools use on-street carpool spaces (61% of car pools formed because of program)
San Francisco, CA	Parking tax of 15% on patrons of for-hire parking facilities Charge of $10/month for van pools in CALTRANS lots versus standard $60/month Long-term parking rates increased in municipal garages and number of monthly contracts reduced to encourage short-term parking	Tax generated $5.4 million in revenues in 1977–78 fiscal year
Seattle, WA	HOV on-street parking permits $5/month versus standard $39/month	193 car pools certified to use 164 spaces (the number of car pools exceeds the number of spaces to ensure high utilization
Washington, DC	Parking tax of 12% on patrons of for-hire parking facilities	Tax generated $8 million in revenues in 1978
Ottawa	Parking rates for federal employees increased from no charge to 70% of commercial rate ($20–$24/month)	Reduction of 23% in federal employees driving to work Auto occupancy estimated to have increased from 1.33 to 1.41 Bus riders in federal work force increased by 16%
U.S. Government	Institute commercial rates in federal government parking facilities	
Pittsburgh, PA	Parking tax of 20% on patrons of all public and private nonresidential facilities that charge for parking	Tax generated $4.8 million in revenues in 1978

essential non-work trips. Table 5.12 sets forth some of the reported Canadian and U.S. experiences with parking management. It is noteworthy that the increase in parking rates for federal employees in Ottawa to 70% of the commercial rate resulted in a 23% reduction in the number driving to work, an increase in automobile occupancy (from 1.23 to 1.41), and an increase in bus ridership (15%) for the federal work force.

The effects of such programs are far-reaching and widespread. They have an impact on:

- auto users;
- transit riders;
- the city centre and adjacent residential neighbourhoods;
- short-term parkers (shoppers and people on personal business);
- long-term parkers (generally commuters);
- downtown employers;
- merchants.

Each of these impacts must be considered in assessing the energy saved by parking management programs.

In formulating a program, consideration must also be given to its potential impact on downtown retail sales and professional services. Good strategies limit the use of parking for work trips, but encourage the use of the limited available space by shoppers and other short-term parkers.

Implementation must consider the nature of the city centre, its employment concentrations and reliance on public transport, the ownership patterns of the existing space supply, and the existence of competitive centres. It is essential to conserve the city centre's vitality and economy, as well as motor fuel.

Table 5.13

Effectiveness of Parking, Pricing, and Restraint Measures

Measure and location	VKT reduction	Elasticity	Remarks
CBD surcharge $2/vehicle (4 major U.S. cities)*	2%–5% in work trips		Estimated
Major employer surcharge $2/vehicle (4 major U.S. cities)*	1%–3% in work trips		
Parking tax 10% (San Francisco)†	2% in CBD	−0.20 to −0.31	31% loss in revenue
Surcharge (Baltimore)‡			
$1/vehicle	0.8% in peak		Estimated
$2/vehicle	1.5% in peak		Estimated
CBD parking cost (Washington)			
$1 increase	0.3%		Estimated
$2 increase	0.6%		Estimated
$3 increase	0.9%		Estimated
Parking cost increase from $3.60 (Manhattan survey)§			
$1 increase	20% car trips	−0.72	Estimated
$2 increase	30% car trips	−0.36	Estimated
$3 increase	40% car trips	−0.29	Estimated
CBD off-street parking (Manhattan model)‖			
15% supply reduction	2.9% in CBD		Estimated
25% supply reduction	4.1% in CBD		Estimated
35% supply reduction	8.0% in CBD		Estimated
Daily parking cost increased by $1#			
Denver	1.6% CBD work trips		Predicted
Fort Worth	1.7% CBD work trips		Predicted
San Francisco	3.3% CBD work trips		Predicted
Daily parking cost increased by $2#			
Denver	3.3% CBD work trips		Predicted
Fort Worth	3.4% CBD work trips		Predicted
San Francisco	6.5% CBD work trips		Predicted

* Ingram, G.K. *Reductions in Automobile Use in Four Major Cities as a Result of Car Pooling and Improved Transit in Transportation.* In Paratransit Services, Transportation Research Board record 650: Washington, DC; 1979.

† Kulash, D. *Congestion Recovery, A Research Summary.* Urban Land Institute paper 1212-99; July 1974.

‡ *The Transportation Engineer and the Clean Air Act Amendments.* One-day seminar, Institute of Transportation Engineers Educational Foundation.

§ *Toward Cleaner Air.* Tri-State Regional Planning Commission: New York; August 1978.

‖ *Selected Estimates of Effects of Strategies to Control Air Quality.* Tri-State Regional Planning Commission interim technical report 2405.

\# Wagner, F.A. *Evaluation of Carpool Demonstration Projects.* Prepared for the Federal Highway Administration; October 1978.

One of the most difficult factors in implementing a parking management program is the mix of public and private space. The level of bond indebtedness, and taxing and land-use requirements and regulations are also significant. Ability and willingness to adhere to regulations and restrictions is another key factor.

Table 5.13 summarizes VKT and energy impacts of various parking management actions. Suggested values for estimating impacts based on this table and current experience are as follows:

- a 1% change in CBD travel for a 5% supply reduction (a 3%-4% reduction in CBD vehicle-kilometres travelled for a 15% supply reduction—New York City estimate);
- a parking elasticity of 0.22 (San Francisco experience);
- a 0.3% reduction in regional VKT for a $1.00 increase in parking costs (Washington estimate);
- a drop of 1%-3% in CBD work-trips for a $1.00 increase in parking costs (Denver, Fort Worth, San Francisco estimates).

4.4 Energy-Savings Calculation

The energy-savings potential of parking management actions depends upon their ability to reduce VKT into and within affected areas and to reduce congestion and increase average speeds.

4.4.1 Analysis Approach

In the general approach to estimating energy savings, there are 3 basic categories of change:

- Motorists who continue to park in the city centre may travel faster, assuming that a sufficient reduction in VKT occurs. The "before" and "after" speeds of these trips should be estimated, along with the savings in litres per kilometre. In reality, though, these speed changes may not occur, and are difficult to estimate.
- The proportion of drivers changing modes should be estimated. These drivers translate directly into VKT and fuel savings.
- Some motorists will change their place of parking. Normally, this proportion and the estimated VKT savings are difficult to estimate. The one exception is where "Park and Ride" facilities are provided; in this case, usage and VKT savings can be readily estimated.

The more practical approach is to estimate only the proportion of drivers that would change modes because of parking actions. The VKT and fuel savings for this group can then be estimated.

The energy savings is represented by the amount of fuel that would otherwise have been used by vehicles that have now been discouraged from coming into an area. A typical formula for this calculation is:

Energy saved = *number of cars removed*
x average round trip distance (km)
x consumption rate (L/km)

An estimate should also be made of the number of trips that are made to another activity centre instead, particularly for any non-work trip purposes. This fuel usage would have to be subtracted from the savings calculated above.

4.5 Application of Measures

4.5.1 Procedures

- Identify potential areas for use of parking-management measures. (High parking demand is the major criterion.)
- Select specific measures that would be appropriate.
- Estimate the effect on travel and the amount of energy saved.
- Implement those measures that are justified by the energy savings and other related benefits.

4.6 Other Information Sources

TEMP has prepared a report on parking policies that can be used to encourage the use of transit and other high-occupancy vehicles. This is available from the Ministry of Transportation and Communications on request, and is entitled **Guidelines for Preferential Treatment of High Occupancy Vehicles.**

5 Auto-Restricted Zones

5.1 Strategy and Objectives

Auto-restricted zones (ARZs) involve the restriction of general-purpose automobile travel in a specific area of the city, such as the Central Business District. Auto restrictions may be in place 24 hours, during peak periods, or during off-peak periods, depending on the purpose and objective of the restrictions. The intent is to restrict travel in the zone specifically, and to discourage auto travel in general. The objective of ARZ measures is to cause people either to shift to transit modes which penetrate the zone or to utilize non-vehicular modes, such as pedestrian travel, for specific segments of their trip.

The primary effect of auto-restricted zones is the reduction of vehicle-kilometres of travel. However, there may also be a VKT increase as a result of the rerouting of significant through trips. Also, because congestion may be increased on parallel or nearby streets, added travel-time and energy consumption here may offset savings in the ARZ.

As a result, auto-restricted zones carry with them a high level of political, business, and public sensitivity, and require careful thought and evaluation.

The general transportation objectives of auto-restricted zones are to:

- reduce congestion on streets;
- reduce travel-time;
- maintain accessibility to area;
- improve transit service;
- encourage a shift to a non-auto mode;
- reduce parking requirements;
- reduce energy requirements;
- reduce accidents.

The institution of an ARZ must consider the scheduling of goods deliveries, transit circulation within the area, automobile circulation around the area, and police enforcement of regulations. Traffic control systems, including signing, are necessary to maximize the efficiency of travel around and through the ARZ.

Auto-restricted zones and pedestrian malls eliminate congested roadways in an activity centre and encourage walking or the utilization of public transportation.

As with exclusive bus lanes and parking management options, these measures are effective only if trips are not diverted to other activity centres. Such restrictions need not operate at all times of the day. They can be effectively utilized during peak periods only.

5.2 Description of Measures

Auto restrictions can be created in specific zones by controlling access and egress points. This limits passage into an area (such as the downtown) to major streets. Since capacity is limited on such arterials, the modal shift occurs because of the congestion or because of the installation of high-occupancy-vehicle lanes which bypass the auto congestion.

Another form of auto control is to permit only certain vehicles into an area. Under a daily licence system, vehicles are banned from an area unless a valid licence has been purchased. Differential prices can be charged to different kinds of vehicles wishing to enter the ARZ.

Similarly vehicle travel could be limited to certain hours. This measure could be enforced by identification stickers, licence-tag designations, etc. While this measure might not achieve significant reductions in vehicle-kilometres of travel (VKT), it would effectively shift traffic from high-congestion time periods to lower-congestion periods, thus reducing peak-period travel. With all auto-restricted-zone schemes, major implementation obstacles include the establishment of priority for the issuance of permits, and the enforcement of the travel restrictions.

5.3 Implementation Experience

The Island Republic of Singapore introduced traffic restraints in its Central Business District in June, 1975. The restraints involved the prohibition of private vehicles and taxis from the congested CBD area between the hours of 7:30 and 10:15 a.m. They were enforced by a combination of pricing and licensing policies.

The results of these actions, summarized in Table 5.14, show that traffic and congestion were reduced during the morning peak period. Traffic built up in advance of the restriction and returned to its "before" level after the restriction was lifted. The maximum flow rate was reduced by about 7% in

Table 5.14

Evaluation of Singapore Automobile Restrictions

Time of day (a.m.)	Before ALS*	ALS in effect 7:30–9:30	ALS in effect 7:30–10:15
	Number of vehicles in each time period		
Before restricted period 7:00–7:30	9 800	11 510 (+17%)	11 073 (+13%)
Restricted period 7:30–9:30	55 313	29 532 (−47%)	—
7:30–10:15	74 014	—	41 198 (−44%)
After restricted period 9:30–10:00	12 775	14 041 (+10%)	—
10:15–10:45	—	—	13 925
	Rate of flow (vehicles/h, average during period)		
7:00–7:30	19 600	23 020 (+17%)	22 146 (+13%)
7:30–9:30	27 657	14 766 (−47%)	15 747 (−43%)
9:30–10:15	24 935	25 443 (+2%)	12 938 (−48%)
10:15–10:45	—	—	27 850
10:45–11:15	—	—	25 378
Peak ½-h	29 948 (8:00–8:30)	28 082 (−6%) (9:30–10:00)	27 850 (−7%) (10:15–10:45)

SOURCE: *Relieving Traffic Congestion: The Singapore Area License Scheme.* World Bank Staff Working Paper no. 281; June 1978.

* ALS, Area License Scheme. 'Before' data were recorded in March 1975; 'in effect' data are for July 1975 when restricted hours were 7:30–9:30 a.m. and for September/October 1975 when they were extended to 7:30–10:15. Figures in parentheses are percent change from March 1975.

Table 5.15

Typical Elasticity Values

Cost factor	Demand factor	Elasticity
Auto trip cost	Drive alone	−0.20*
	Car pool	+0.40*
	Transit	+0.40*
Auto operating costs	Bus demand	+0.21 work†
		+0.12 non-work†
Auto parking costs	Bus demand	+0.33 work†
		+0.12 non-work†
Toll costs	Auto use	−0.20 (−0.17 to −0.22)‡
10% increase in New York City tolls/parking	Drive in peak	−0.15§

* Trumble, J.W., S.C. Kupferman, and D.K. Boyle. *Draft Energy Impacts of Transportation Systems Management Actions.* New York State DOT; July 1981.

† R.H. Pratt Assoc. Inc. 1976.

‡ Levinson, H. et al. *Estimating Behavioral Response to Peak Period Congestion.* Transportation Research Board record 767: Washington, DC; 1980.

§ Adapted from the New York City East River Capacity Management Study.

the morning peak period, although substantially fewer vehicles entered the restricted area. Evening peak-period traffic was reduced by about 3%-4%. Opinion surveys taken after implementation showed acceptance of the traffic restraint system, but expressed the opinion that increased parking fees would adversely affect downtown economic vitality.

There are many other examples. The Gothenburg traffic compartment scheme represents another approach to restricting traffic into a designated cordon area. Traffic cells or compartments within the scheme were implemented by establishing peripheral catchment areas where transit service is offered in designated central areas. Through traffic was rerouted. The scheme resulted in:

- elimination of traffic congestion;
- reduced travel in the area;
- increased distance travelled by through traffic at higher speeds;
- better performance by transit vehicles in the CBD.

However, it is significant that Gothenburg is a relatively small city which is well served by transit.

In Los Angeles, a potential reduction of 0.6% of regional VKT from an auto-free zone in the down-

Table 5.16
Energy Analysis of Road Pricing Actions — Example Calculation

	Drive alone	Shared ride	Transit
1. Daily trips (one-way) for analysis period			100 000
2. Base market share (1.0 = 100%)	0.70	0.20	0.10
3. Daily trips by mode, 1 × 2	70 000	20 000	10 000
4. Average trip length (km)	11.3	14.5	10.5
5. Vehicle occupancy	1.0	2.5	60
6. Base vehicle-km of travel, 3 × 4 ÷ 5	791 000	116 000	1750
7. Percent change in drive-alone trip cost 10%			
8. Demand elasticity for drive-alone trip cost (direct for Drive alone, cross elasticities for Shared ride and Transit)	−0.20	+0.40	+0.40
9. Percent change in market share, 7 × 8	−2%	+4%	+4%
10. Revised market share, 2 × 9 + 2	0.687	0.209	0.104
11. Revised vehicle-km of travel, 1 × 10 × 4 ÷ 5	776 310	121 220	1820
12. Change in vehicle-km travelled, 11 − 6	−14 690	+5220	+70
13. Car-left-home factor (use 0.6)	0.6	—	—
14. Adjusted vehicle-km travelled, 12 × 13	−8814	+5220	+70
15. Fuel economy by mode (km/L)	7.5	7.5	2.1
16. Change in daily energy consumption, 14 ÷ 15 (L)	−1175.2	+696.0	+33.3
17. Adjustment factor to convert diesel fuel to gasoline energy equivalent			1.104
18. Adjusted daily energy consumption, 16 × 17 Transit only (L)			+36.8
19. Total change in daily energy consumption, all modes (L)			−442.4
20. Annual energy saving, 19 × 250 working days (L)			110 600

SOURCE: Trumble, J.W., S.C. Kupferman, and D.K. Boyle. *Draft Energy Impacts of Transportation Systems Management Actions.* New York State Department of Transportation; July 1981.

town business area has been predicted, but would require extensive changes in parking and land-use patterns.

5.4 Effectiveness of Measures

The potential for energy reduction through small-scale auto-free zones is small, but large-scale auto-free zones would require a great deal of land-use and institutional change. The estimate for energy consumption reduction is less than 0.5%.

There has also been empirical experience with auto-free zones which suggests that traffic reductions can actually enhance the attractiveness of commercial districts when adequate alternative access is provided; e.g., transit and fringe parking. A study by the Organization for Economic Cooperation and Development (OECD) of the effect of traffic bans indicates that traffic bans do have a positive effect on retail sales. In Vienna, shop-owners reported a 25%-30% increase after the traffic ban went into effect. In Norwich, England, all but two shops in the exclusive area had more business, and some experienced an increase in sales of 10% or more. In Essex, the increase in trade has been reported to be between 15% and 35% depending on the type of shop; and, in Dover, between 10% and 20%. In Tokyo, of 574 shops surveyed, 21% showed an increase in sales, 60% no change, and 19% a decrease: 74% of the merchants interviewed pronounced themselves in favour of the scheme. The OECD Study also reported that, in Florence, merchants went on strike to protest their street's exclusion from a traffic-ban zone. These examples indicate that commercial areas do not necessarily require auto access in order to be successful, and that transit may be capable of providing suitable accessibility to non-work destinations.

5.5 Energy-Savings Calculation

Potential energy savings depend upon the number and length of auto-driver trips that would be diverted to other modes as a result of introducing a pricing scheme and/or auto-restricted zones.

5.5.1 Analysis Approach

Demand elasticities should be used to estimate the reductions in auto driver trips that would result from proposed measures [10]. Because there has been little experience in North America with

congestion pricing, care should be used in the application of measures and in the assessment of results — changed origin/destination patterns may occur, rather than changed modes. A study by Levinson [11], for example, found that motorists faced with peak-hour toll surcharges considered, in order of preference, the following actions:

- changing routes to avoid tolls,
- switching time of travel,
- using transit,
- joining a carpool,
- travelling less.

The values shown in Table 5.15 can be used to estimate impacts of changes in road pricing in the absence of more specific data. The estimated reductions in VKT by driver-only cars will be partly offset by the increased number of carpool and bus trips. Therefore, wherever possible, allowances should be made for these increases. In other words, the estimated reductions in driver-only trips represents the *maximum* likely energy savings.

5.5.2 Analysis Steps

The analysis steps outlined in Table 5.16 are based on procedures initially developed by the New York State Department of Transportation [9]. The key elements are as follows:

1. Estimate the total one-way person-trips by mode for the hours to be studied (i.e., peak hours) and the respective modal shares, trip lengths, and occupancy data (Steps 1-5).
2. Estimate the vehicle-kilometres of travel by each mode (Step 6).
3. Estimate the change in total trip cost for auto drivers as a result of the proposed pricing measure. This normally involves the line-haul operating cost and out-of-pocket costs, plus the pricing disincentive (Step 7).
4. Estimate the elasticity of demand (trips) for each mode, with respect to price. Most pricing schemes would affect only the drive-alone total cost; therefore a direct elasticity for drive-alone and a cross elasticity for shared-ride and transit-usage are required. Default estimates are outlined for these values (Step 8). Alternatively, values shown in Table 5.15 or specific local values could be used. Where cross-elasticity data are not available, an "upper-bound" estimate can be prepared by considering only the solo auto driver.
5. Estimate the new market shares for each mode by applying the elasticities to the changes in costs (Steps 9 and 10). Estimate the revised vehicle-kilometres, and changes in VKT by mode (Steps 11 and 12). Discount the auto-driver VKT by a factor of 0.6 to account for use of the "car left at home" (Steps 13 and 14).
6. Estimate or look up the appropriate over-the-road fuel economy by mode for the analysis year. Use a factor of 56 L/100 km for transit buses (Step 15). Divide the rates into the VKT to find the daily fuel consumption by mode (Step 16).
7. Adjust the diesel litres for transit by a factor of 1.104 to convert to daily gasoline energy equivalents (Steps 17 and 18).
8. Add the total daily energy savings by all modes to find the change in daily gasoline savings (Step 19). Expand to an annual basis by multiplying by 250 (Step 20).

The basic assumptions for the example shown in Table 5.16, as developed by NYS DOT are as follows:

- A 10% peak-period surcharge should be introduced for driver-only cars entering the CBD between 7 and 9 a.m.
- Base travel data are as follows:

A.M. Peak-Period Person-Trips, Peak Direction

70% - auto: driver alone	- 11.5 kilometres
20% - auto: shared ride	- 14.5 kilometres
10% - transit	- 10.5 kilometres

5.6 Implementation Procedure

- Determine level of congestion in major activity zones, usually the CBD.
- Identify the type of auto restrictions that could best be applied without restricting business activity.
- Design treatment, ensuring that capacity for movement of people is available.
- Evaluate energy savings resulting from treatment.
- Implement measure and monitor its effects.

5.7 Other Information Sources

A number of cities have implemented ARZs. Reports on their design and impacts are available for information.

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Appendix

Land-Use Planning — Simplified Worksheet

1. Describe proposal

Single-family homes	______ units
Single-family attached	______ units
Low-rise apartments	______ units
High-rise apartments	______ units
Location	______

2. Estimate annual energy intensity by unit type (from bottom line of Table 5.3 for Toronto and Ottawa or Table 5.4 for other cities

Single-family homes	______ MJ/unit
Single-family attached	______ MJ/unit
Low-rise apartments	______ MJ/unit
High-rise apartments	______ MJ/unit

3. Obtain total annual energy (multiply energy per unit by the number of units of each type)

Single-family homes	______ MJ
Single-family attached	______ MJ
Low-rise apartments	______ MJ
High-rise apartments	______ MJ
Total	______ MJ

Land-Use Planning — Detailed Worksheet

1. Describe proposal

Single-family homes	______ units
Single-family attached	______ units
Low-rise apartments	______ units
High-rise apartments	______ units

2. Estimate person-trips by type of unit. The form shown here is for one type of unit; use a separate form for each type.

	Auto	Transit	Total
% person-trips by mode	______	______	______
Number of daily urban person-trips/unit	______	______	______
3. Estimate average trip length (km)	______	______	
4. Estimate daily person-km/unit, 2 × 3	______	______	
5. Estimate annual person-km/unit, 4 × 300 days	______	______	
6. Estimate modal energy intensity (MJ/person-km)	______	______	
7. Estimate annual transport energy, 5 × 6 (MJ/unit)	______	______	______
8. Estimate total building construction and maintenance energy (MJ/unit)			______
9. Obtain total energy, 7 + 8 (MJ/unit)			______
10. Weight by number of units, 1 × 9 (MJ)			______

Energy Analysis of Road Pricing Actions — Worksheet

	Drive alone	Shared ride	Transit
1. Daily trips (one-way) for analysis period			______
2. Base market share (1.0 = 100%)	______	______	______
3. Daily trips by mode, 1 × 2	______	______	______
4. Average trip length (km)	______	______	______
5. Vehicle occupancy	______	______	______
6. Base vehicle-km of travel, 3 × 4 ÷ 5	______	______	______
7. Percent change in drive-alone trip cost ______			
8. Demand elasticity for drive-alone trip cost (direct for Drive alone, cross elasticities for Shared ride and Transit)	______	______	______
9. Percent change in market share, 7 × 8	______	______	______
10. Revised market share, 2 × 9 + 2	______	______	______
11. Revised vehicle-km of travel, 1 × 10 × 4 ÷ 5	______	______	______
12. Change in vehicle-km travelled, 11 − 6	______	______	______
13. Car-left-home factor (use 0.6)	0.6	—	—
14. Adjusted vehicle-km travelled, 12 × 13	______	______	______
15. Fuel economy by mode (km/L)	______	______	______
16. Change in daily energy consumption, 14 ÷ 15 (L)	______	______	______
17. Adjustment factor to convert diesel fuel to gasoline energy equivalent			1.104
18. Adjusted daily energy consumption, 16 × 17 Transit only (L)			______
19. Total change in daily energy consumption, all modes (L)			______
20. Annual energy saving, 19 × 250 working days (L)			______

SOURCE: Trumble, J.W., S.C. Kupferman, and D.K. Boyle. *Draft Energy Impacts of Transportation Systems Management Actions*. New York State DOT; July 1981.

Impact of Work Schedule Changes — Worksheet

	Before change (A)	After change		Difference A − (B + C)
		Participants (B)	Others (C)	
1. Total target workers	______	______	______	
2. % car drivers	______	______	______	
3. Number of car drivers, 1 × 2	______	______	______	
4. Trip length (km)	______	______	______	
5. Daily VKT, 3 × 4 × 2 trips/day	______	______	______	
6. Annual VKT, 5 × 250 days*	______	______	______	______
7. Adjustment for car use at home†	1.0	______	1.0	
8. Adjusted annual VKT, 6 × 7	______	______	______	______
9. Speed (km/h)	______	______	______	
10. Fuel consumption (L/km) at above speed	______	______	______	
11. Annual fuel consumption, 8 × 10 (L)	______	______	______	______

* Step 5 × 200 days for compressed work week.

† Adjustment factor is 1.0 except for compressed work week when it is 1.12.

Ontario

Ministry of
Transportation and
Communications
Hon. James W. Snow
Minister

Ministry
of
Energy
Hon. Robert Welch
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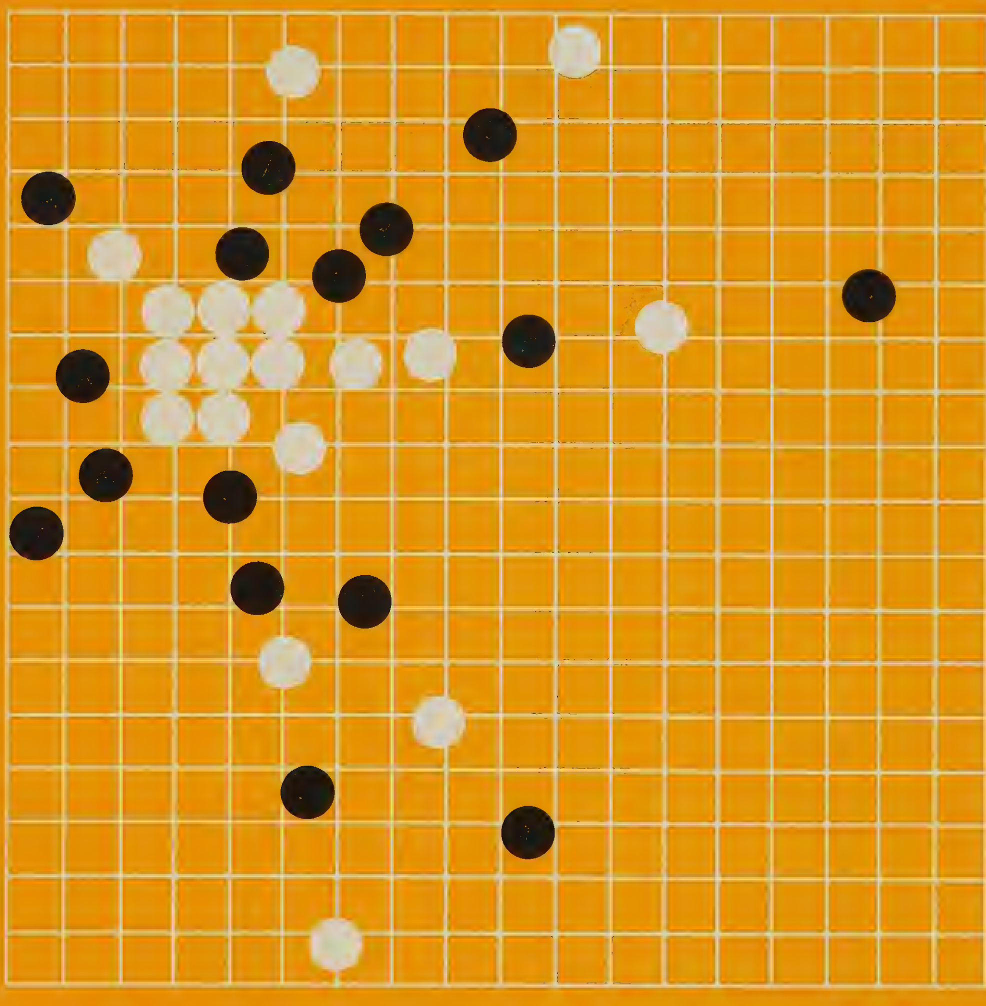
Energy
Ontario

Transportation Energy Analysis Manual

6: Municipal Fleet Management



The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM
Transportation Energy Analysis Manual

6:
Municipal Fleet Management

Published in consultation with
The Municipal Transportation Energy Advisory Committee

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Preface

The purpose of the Transportation Energy Analysis Manual (TEAM) is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within their municipality. TEAM is organized into ten chapters which outline the principal technical ways to conserve energy through transportation improvements, and discuss their resultant impacts and the major issues.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is a crucial public-sector level because these decision-makers are called upon to deal with the day-to-day lives and activities of the citizens residing within their municipalities. Energy conservation is an everyday, on-going affair.

The **Transportation Energy Analysis Manual** will consist of chapters on the subject areas listed below. The Manual is being produced chapter by chapter as each is completed. These in turn will be updated as considered necessary.

Executive Summary

1. Program Overview
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Energy Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Program Management
10. Energy Analysis Methods

This chapter, **Municipal Fleet Energy Management**, focuses on and highlights the energy conservation activities which would be applicable for implementation in the management of a municipality's fleet of vehicles.

Additional information on the Manual or on any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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Tables

Figures

1 Overview

1.1 Introduction

A recent survey of municipal fleets in Ontario showed that their costs for regular, leaded gasoline had risen by 45% over a one-year period. This chapter deals with the management of municipally owned or operated vehicles and, more specifically, with the methods and measures which can reduce fuel consumption. In this way, the impact of price increases and shortages can be modified, and the use of petroleum products reduced. A fleet fuel-management program can be expected to achieve fuel savings of up to 30%, much of this in a short period of time. The chapter is divided into four discrete sections. The first provides overviews of the current status of municipal fleets and some of the management systems which monitor energy use and can be used as decision-making tools. The second details the most applicable fuel conservation measures. The third provides descriptions of analysis methods which can be employed in undertaking comparative evaluations. Finally, the last section suggests an implementation sequence for the various conservation options.

The first question which must be asked in developing any fuel conservation program is, "Why do it?" It is impractical to suggest that any motivation other than "dollars and cents" should dictate what activities are undertaken. There are, of course, the non-economic and political motivations which can add some pressure; however, in the long term, the cost trade-offs must be advantageous to be justifiable.

Throughout this chapter, the primary management goal is assumed to be minimizing overall operating costs of municipal fleets during a period in which the relative cost of fuel is increasing very rapidly. The intent is to demonstrate that conservation policies and actions are economically sound and will continue to be so in the years to come.

1.2 Municipal Fleet Management Goals

At the outset, it is worthwhile to state the basic goals associated with good fleet management, as it is easier to define and promote changes in current management methods if they can be linked to well-defined performance goals. As a minimum, the goals of municipal fleet management are:

- to provide departments or agencies with vehicles in good operating condition;
- to minimize the operating costs of the vehicles;
- to assist in the proper specification of vehicles to minimize capital investment;
- to maintain a vehicle-cost record system to judge past performance and budget for future expenditures.

In addition to these points, the following items could be added as special objectives related to energy conservation:

- strategically, to plan the composition of the fleet in such a way as to minimize its sensitivity to economic dislocation (e.g., a shortfall in gasoline supply);
- to maintain a fleet which is exemplary (in the area of fuel supply) to private sector fleet managers.

These goals form the basis for the evaluation of energy-conservation measures proposed for the use of municipal fleet managers.

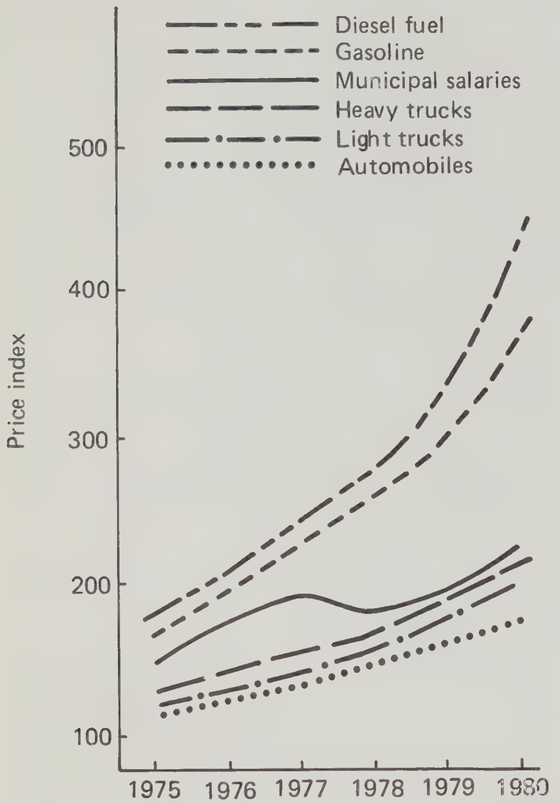
1.3 Trends in Fleet-Operating Costs

Of all the elements that contribute to the cost of operating a vehicle fleet, fuel costs have been inflating at by far the highest rate. Figure 6.1 plots the relative price increases for the major cost components. These data clearly show that, compared to capital and labour costs, fuel costs increased the most over the last five years and the rate of increase has been accelerating in the past few years. Thus, between 1979 and 1980, the cost of fuel rose 25-30%, while other costs inflated only 10-12%.

In the next ten years, this relative increase in fuel costs can be expected to continue, according to the current federal government policies and forecasts. While the rate of price escalation may moderate in the latter half of this decade, the underlying conclusion must be that energy costs will eat up a higher percentage of total operating costs in the future if no conservation action is taken. At the same time, it is expected that the

Figure 6.1

Trends in Fleet Operating Cost Components



SOURCE: Statistics Canada 62-011 and 72-009.

*Note these values are indices, based on 1971 values set at 100, and thus reflect the relative change within the category. They do not reflect accurately the absolute differences between categories, e.g., diesel fuel and gasoline currently have the same price.

cost of money will be higher than the historical average, making any equipment purchase a larger drain on the total municipal budget. Finally, labour costs overshadow all the equipment costs. The increase in labour cost, while recently below that of other goods, will probably return to a higher rate of increase in the future. Thus, if municipal costs are to remain at or below the overall inflation rate, careful analysis of manpower and equipment utilization will be required.

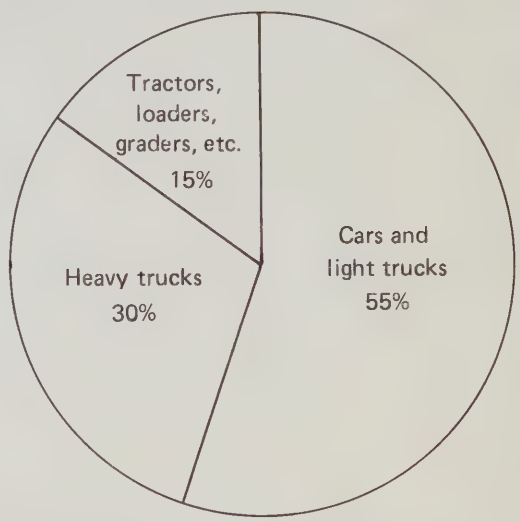
All of these factors point to a need for re-evaluation of municipal purchases and operations in order to minimize expenditures and avoid some of the known future-cost pitfalls. By far the largest of these is that of energy. Fortunately, control of energy costs can be achieved by the selection of practical and economical vehicle-management options such as those described in the following pages. By following the described methods, it is not unreasonable to expect up to a 30% fleet-cost reduction over a relatively short period (two to three years). These results have already been achieved by some municipalities and should be achievable by most others. Remember, "If we each save a little, we all save a lot."

1.4 Present Fleet Composition

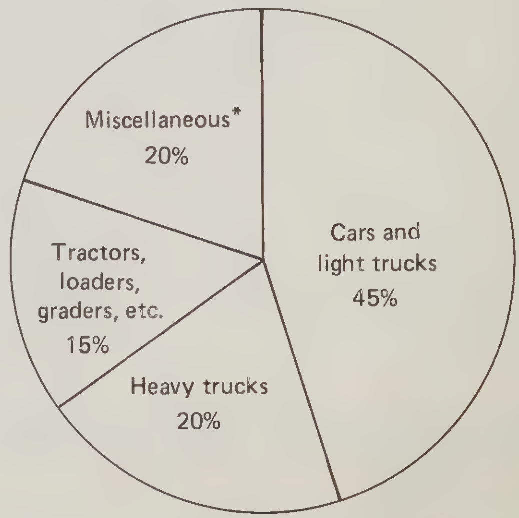
Although there is no comprehensive inventory of municipal liquid-fuel powered equipment for Ontario, some rough estimates can be developed based on reviews of a limited number of Ontario municipalities. The gross number of municipal vehicles will vary as a function of population, number of road-kilometres, and the climatic zone in which the municipality is located. Further, the upper-tier governments (regional governments), because they fulfill different public service roles,

Figure 6.2

Typical Municipal Fleet Composition



Upper-tier governments (regional, metropolitan)



Lower-tier governments (cities, towns)

*Compressors, chain saws, lawnmowers, etc.

have different fleet structures and, generally, a lower per-capita fleet size than the lower-tier governments (cities, towns, etc.).

Approximations of the proportions of each major size group of vehicles by level of government are shown in Figure 6.2. These estimates exclude garbage, fire, and police vehicles, as the assignment of these varies substantially between municipalities (e.g., regional versus city police fleets, contracted versus city-run garbage collection). These estimates indicate that 45-55% of the typical fleet consists of light-duty vehicles (less than 2200 kg) while 20-30% are heavy trucks. The remaining vehicles are hourly-operated equipment (e.g., loaders, tractors, sidewalk plows, etc.)

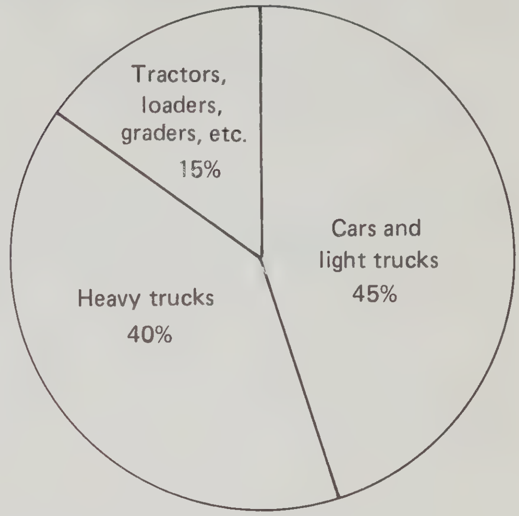
Police fleets are made up predominantly of cars (mostly full-sized), with fleet size determined by the population and geographic size of the service area. Fire and garbage fleets contain uniformly large vehicles of specialized design, whose numbers are also determined by local conditions.

1.5 Present Fleet Energy Use

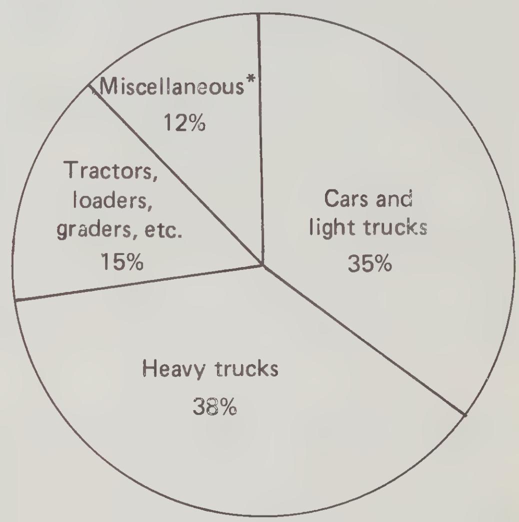
From the data obtained from a sample of municipalities, an overview of the distribution of total fuel consumption was developed (see Figure 6.3). As with the fleet-composition data, these percentages are generalized values and serve only to indicate the approximate distribution. Each municipality will be different, because of all the factors which affect fleet size. As well, the extent to which the municipality has already introduced fuel conservation programs and the total vehicle use in a given year will alter fuel-use distribution (e.g., low-snow years will skew the distribution to higher car and light-truck percentages because the heavy trucks are not used as much).

Figure 6.3

Fuel Consumption Distribution



Upper-tier governments (regional, metropolitan)



Lower-tier governments (cities, towns)

*Compressors, chain saws, lawnmowers, etc.

While these proportions may be indicative of the "average" fleet, the first task which should be carried out in any energy conservation program is the estimation of the present fuel-use pattern (see Section 2.2). The results of this task can then be used as the baseline condition for future energy reports. The objective is to identify the most significant energy users and institute conservation actions on these vehicles. This approach has the greatest short-term effect on total fuel use; more investment can be justified in these vehicles than in vehicles that account for only a small portion of total fuel consumption.

1.6 Role of an Energy Conservation Manager

Along with changes in operating and record-keeping procedures, there is a requirement in the management structure for one person or group to be charged with the task of promoting and monitoring energy conservation in the municipal fleet. It is important to note that the mandate of this energy conservation manager (group) generally is not restricted to the vehicle fleet, but includes municipal buildings and the other transportation energy conservation measures outlined in this manual. It is extremely important to prevent the development of an adversary situation between the energy manager and the fleet manager. These two positions must work towards the common goal of cost reduction through better energy management, and avoid internal jurisdictional squabbles.

While an energy conservation program can be successful without designating a manager's position, all the municipalities reviewed which had

done so appeared to have more aggressive, better documented, and more effective programs than those municipalities which did not assign such a position. In addition, the explicit recognition of an energy conservation program provides the politicians and the public with a contact point for questions and suggestions concerning municipal efforts in the area.

An additional role of the energy manager is to motivate staff to participate actively in the program. While it would be nice to think that upon hearing the word, "Conserve," people will do it, that is not the way of the real world. In order to create the most effective program, it is important to get everyone working towards the same goal (and wanting to!). In this regard, the following points should be observed:

- the program goals should be realistic and achievable;
- local council members and senior management should be supportive and participate in the program;
- a reporting system should be established to inform employees of achievements as quickly as possible;
- an award system should be established to recognize good performance (e.g., the department with the greatest reduction in fuel use or lowest fuel-consumption rates);
- the program should be tied to fuel and budget savings by tallying fuel and dollar savings to date;
- departments should be reminded that any monies saved in the program can be used for support of their primary functions: thus conservation can act as a budget extender;
- the "news" should be distributed by frequent short notices or newsletters rather than through one composite information piece;
- promotional items, such as bumper stickers, should be used to keep the program awareness high in the minds of both the employees and the public.

2 Conservation Measures

2.1 General Discussion

Although the fleet manager may sometimes feel that he is faced with a bewildering array of fuel-conservation actions, there are only a handful of measures which can practically be applied. These individual measures are described in the following section in a way which outlines the basic activity, its effectiveness, and examples of its use.

The management options can be sorted into three primary categories:

- *information analysis and reporting* — in which improved information is provided on the use of fuel so that the progress or performance of the program can be measured;
- *vehicle productivity* — which is increased through improved utilization, routing changes, or changes in vehicle type;
- *vehicle efficiency improvements* — in which the basic fuel-consumption rate of the vehicle is reduced through design or maintenance changes.

For each major measure, a brief description is given, broken down into the following components:

- Objective
- Description
- Effectiveness
- Implementation Experience
- Summary

2.2 Energy Use Audit and Reporting

Objective

The overall objective of this measure is to establish a reporting, evaluation, and organizational system which views energy use as a discrete management element rather than a component of overall vehicle cost. When energy use is isolated in this way, performance can be monitored more effectively. The intent of this change is not to alter the financial basis of fleet management, but rather to augment the existing cost-record system so that changes in costs can be related to changes in the type or amount of fuel used. In this way, the fluctuation in total fleet operating costs can be related to changes in the cost element with the highest rate of growth — the fuel.

Description

The first requirement for any fleet energy-management program is the establishment of an information-recording system which monitors fuel use discretely. Without such a system, it is virtually impossible, in view of the rapid increase in the price of fuel, to isolate changes in fuel use from fuel cost. Fortunately, in most municipalities, the cost-accounting system can be altered to provide an energy-accounting data base. The usual accounting practice is to convert fuel use into a fuel cost before it is input into the financial data base (this assumes a computer-based record system; however, a manual system usually follows the same pattern). In order to create an energy-use data base, the fuel dispensing information must be carried through the system (or a complementary system) so that the **volume** as well as the **cost** of fuel is accessible for report generation from the data base. Once this change has been made, a variety of energy reports can be created.

It is important to ensure that the information being put into the system is accurate. In this regard, the most important element is the control and recording of fuel dispensing. This is doubly important as the relative increase in the price of fuel will also increase the inclination for fuel pilferage.

In addition, for vehicle-performance monitoring purposes, it is useful to obtain an odometer reading at each fill-up. Alternatively, odometer readings at weekly, biweekly, or monthly intervals can be used to monitor vehicle use and fuel consumption, although this method builds some error into the fuel consumption calculation as the fuel tank levels will not be consistent (e.g., odometer reading could be taken with a full tank one week and an empty tank the next).

All this information can be recorded manually, either by the driver or the fuel dispenser, or automatically (see example in Figure 6.4) through the use of card- or key-activated fuel-security systems (e.g., Gasboy or Keytrol). The accuracy of the data is highest with the automatic systems

but so is the cost, and with the exception of the latest models, there is generally no accommodation for recording odometer readings. The choice of the appropriate dispensing control system is highly dependent upon the existing system, the size of the vehicle fleet, and the source of fuel supply ("municipally dispensed" versus "purchased at retail pumps"). No system is fool-proof; the best control can be achieved only by diligent monitoring of the per-tank fuel consumption for each vehicle in order to identify and query any significant fluctuation in fuel consumption rates. This monitoring can be achieved equally well by using any one of the fuel dispensing systems, as the control lies in the system of management, not in the information-collection system. (Figure 6.4 shows a fuel delivery record slip of the type used in the Niagara Region.)

With these basic fuel-use data, a routine reporting system can be developed, through which performance can be measured and future programs planned. There are a variety of formats for these reports and municipalities should not expect to have a standardized report format. However, there are basic elements which are necessary. These basic report elements are:

- *total fuel consumed* — segmented by fuel and vehicle types;

Figure 6.4

Fuel Record Example

THE REGIONAL MUNICIPALITY

OF NIAGARA

— FUEL USAGE —

REG. GASOLINE ☐ DIESEL ☒

UNLEADED ☐ PROPANE ☐

UNIT NO. 402

PUMP LOCATION 70

ODOMETER READING 46591

DELIVERY NUMBER	METER FINISH READING	10ths
AA 3 2 2	0 0 4 6	8
AA 3 2 1	0 0 0 0	0
PREVIOUS DEL. NUMBER	METER START READING	10ths
TOTAL	46	8

DATE FEB 11 19 82

DRIVER Truck Driver
SIGNED

42577 INSERT FACE DOWN BOTTOM FIRST

- *vehicle operating costs* — segmented by cost elements (e.g., fuel, parts, labour, etc.);
- *total vehicle-kilometres (and/or hours)* — segmented, if possible, by gross operational function (e.g., snow plowing, administration, patrol, etc.) and type of vehicle;
- *fuel consumption rate (L/100 km)* — segmented by vehicle type, operational function, and fuel type;
- *a summary status report* — comparing the present to previous periods and useful as a forecast for the next period.

The main focus of the report should be on describing four specific aspects of the conservation program:

- the fuel and vehicle usage patterns of the present fleet;
- fleet operating-cost changes;
- net energy-use reduction, both in quantity and energy content (e.g., joules);
- identification of major deviations from norms (e.g., high-consumption vehicle or driver).

Effectiveness

Although it achieves no direct conservation, improved management information is a vital component in a conservation program, since it provides the capability to quantify the existing operations and to document the effectiveness of other measures. Further, the production of a fleet energy report focuses attention on the program and can be used to plan, enhance, and expand it.

Implementation Experience

Several municipal fleets have instituted energy data-acquisition and reporting systems. Some examples are:

- Niagara Regional Municipality,
- City of Ottawa,
- Borough of Scarborough,
- Metro-Toronto Police,
- City of Burlington,
- City of Oakville.

All of these municipalities have reported excellent acceptance of the reports and an increase in their ability to determine the effectiveness of the fuel conservation programs which they have instituted.

Summary

The need for good record-keeping procedures and a formal reporting system cannot be overstated. Without such a system, no quantitative evaluation of the progress towards reducing fuel costs and consumption can be made.

2.3 Dieselization

Objective

One of the most popular methods of decreasing fuel consumption is to switch from gasoline to diesel engines at the time of vehicle replacement. This action decreases the fuel consumption rate of individual vehicles and thus reduces the total amount of fuel used by the fleet.

Description

The attractiveness of the diesel engine lies in its:

- use of an inherently more efficient thermodynamic cycle, which reduces fuel consumption;
- use of diesel fuel, which is 4-6% cheaper than unleaded gasoline on an energy basis;
- potentially longer engine life and lower engine maintenance requirements.

Offsetting these benefits is the higher initial cost of diesel-engined vehicles (differences of $4-5000 for large trucks and $1-2000 for small trucks and cars). Furthermore, maintenance training will be required in some operations and, when diesels are used in small trucks and cars, acceleration rates will be lower than with equivalent gasoline-powered units.

Effectiveness

The principal applications of dieselization in municipal fleets surveyed recently have been in the area of heavy trucks and garbage vehicles, where fuel consumption reductions of 30-50% have been achieved. Maintenance benefits are still unclear because of the relatively short usage periods (one to two years). Most municipalities have found no significant problems with the diesel units and report that the added cost premium has a payback period of three to five years, depending on vehicle-use and fuel-price differentials.

In addition, most fleet managers are expecting that the diesel-equipped vehicles will be capable of extending the normal gasoline-powered trucks' service life by one or possibly two years. If the service life is extended, then the overall advantage of diesels will be even higher than current calculations indicate.

A word of caution should be injected at this juncture. Because of the specific characteristics of the diesel engine, extra care must be taken in specifying the engine-size and transmission combination. Further, some specific engine models have had better service histories and fuel consumption records than others. It is wise for the fleet manager to check with other municipalities and operators on their experience with particular engine configurations under similar operating conditions, to ensure the best product selection.

The use of diesel power-plants in small trucks has received a generally negative reaction from those municipalities who have experimented with them. The reason for their poor performance (high repairs) appears to be related to the specific engine design rather than to the general unsuitability of diesel engines, since the use of diesels has been highly rated by many diesel-powered-car users. In all probability, the specific design-related problems will be corrected by the manufacturers in the next few years, at which point the use of diesel engines in small vehicles will be more economically sound.

Implementation Experience

The current experience with diesels has been generally favourable, with major programs having been undertaken by, among others:

- Oakville,
- Oshawa,
- Durham,
- Ottawa,
- Ottawa-Carleton,
- Burlington,
- Nepean,
- Scarborough,
- North York.

Summary

In summary, the application of diesels is generally cost-effective (always do the purchase evaluation first!) in:

- large trucks (20 000 lb / 9100 kg GVW) which travel more than 10 000 km per year;
- large trucks with a high amount of idle time;
- small cars and light trucks with high annual use (e.g., greater than 25 000 km).

2.4 Alternative Fuels

Objective

In some cases, operating costs can be lowered by switching to another type of fuel. Typical alternative fuels include:

- propane (LPG),
- compressed natural gas (CNG),
- liquid natural gas (LNG),
- gasohol (ethanol/gasoline),
- methanol,
- electricity,
- hydrogen.

Of this list, only propane is currently viable. The others are either in various developmental stages, from concept through to demonstration (and therefore not yet suited to the "real" world of the municipal fleet) or, as in the case of gasohol, not generally available in Ontario. The most advanced of the other more readily available alternatives are electrical and compressed natural gas systems. Each is currently in the demonstration stage.

Description

Both propane and compressed natural gas have similar system characteristics. Both:

- can be used with existing gasoline engines;
- use a gaseous fuel (at engine inlet temperatures and pressures);
- allow on-board storage of fuel in pressurized tanks;
- require a gas/gas mixing carburetor;
- require specialized fuel-handling facilities.

The principal difference between the two fuels lies in the fuel (energy) storage capacity of the systems. The fact that propane is stored as a liquid enables it to have three to four times the energy density of compressed natural gas; i.e., three or four times the per-tank driving range for the same size fuel tank. Because of this higher energy density, propane is, at the moment, commonly viewed as the superior alternative fuel.

The development of propane systems has been stimulated by the introduction of government incentives and demonstration programs. As a result, motor vehicle manufacturers are now starting to offer propane as an original-equipment option. The purchase of vehicles already fitted with a propane system is preferable to retrofitting the equipment after purchase, as it avoids the need for specialized installation services, and thus decreases costs. A major area of uncertainty with propane is the resale value of the equipment. However, this question only affects the life-cycle calculation of benefits and not the payback period analysis or fuel conservation benefits.

Effectiveness

The economic advantages of propane lie primarily in the lower cost of the fuel (currently there is no road tax applied to it). However, fuel efficiency improvements are theoretically possible because of the improved ignition characteristics of the fuel (even though the information derived from the "Drive Propane" program has not yet shown any decrease in energy consumption with propane). In addition, there are some marginal maintenance savings possible (primarily through longer plug and oil life) in comparison to vehicles using unleaded fuel. These maintenance savings are higher when compared to costs for vehicles using leaded fuel than to those for vehicles using unleaded fuels, because of the higher baseline costs of vehicles requiring leaded fuel.

Typical light-duty fleets have been able to reduce their direct fuel costs by 35-40% by using propane. The attractiveness of this saving is dependent upon the original equipment cost ($1000-1600), vehicle use, and expected service life.

The savings in terms of gasoline or diesel fuel, though, amount to 100% of previous consumption.

Implementation Experience

The use of propane in fleet operations has been increasing rapidly in Ontario as a result of the economic incentive program of the Ontario and Federal governments and the "Drive Propane" program of the Government of Ontario. The current application areas of propane in municipal fleets are:

- police vehicles (Niagara Regional Police, Ontario Provincial Police);
- garbage trucks (North York);
- pick-up trucks and vans (Ottawa, Oakville, Niagara Regional Municipality).

Because of the short time in which large-scale use of propane has been possible, the actual savings are not well documented. For up-to-date information on the economics of this measure, contact:

Drive Propane
Ontario Ministry of Transportation
and Communications
1201 Wilson Avenue
Downsview, Ontario
(416) 248-7296

Summary

Alternative fuels can have a significant impact on petroleum needs. The use of propane in municipal fleets, for example, appears to be an economically sound cost-saving measure. It is best applied in larger fleets where the fuel supply system and personnel training costs can be spread over more vehicles, thus reducing these fixed costs. Further, it is imperative that a good fuel distributor be available locally to prevent any supply problems. Finally, it is preferable, in the long run, to purchase a propane system as an original equipment option, rather than to perform a retrofit on an existing vehicle.

2.5 New-Vehicle Resizing

Objective

One of the most significant conservation changes which can be instituted is the resizing of the fleet vehicles. This action does not necessarily mean reducing the size of vehicles; it can also mean increasing the vehicle capacity in order to reduce the number of trips and the total kilometres of vehicle use.

Description

The main objective is to re-evaluate the role the vehicle is meant to play and to define the vehicle in terms of that role. Thus, rather than simply replacing a ¾-ton truck with an updated version, the fleet manager should investigate the possibility that a ½-ton truck may be sufficient if the ¾-ton truck was rarely filled to capacity. By downsizing the vehicle, both capital cost and fuel consumption are reduced for the municipality. Conversely, if the vehicle was chronically loaded to its maximum payload, then increasing the size of the vehicle will allow the same amount of material to be hauled in fewer trips.

The process of re-evaluation can be a standard operating procedure that follows the decision-making process outlined below.

1. Evaluate vehicle as due for replacement.
2. Review use and maintenance costs of present vehicle.
3. Discuss past vehicle use with operating group.
4. Identify physical under/over-capacities of present vehicle.
5. Review with suppliers available vehicle options which have more suitable capacity.
6. Review options with and obtain agreement from operating group.
7. Purchase vehicle.

Effectiveness

Some municipalities have been very successful in modifying their vehicle purchases by following this vehicle-by-vehicle analysis process in conjunction with suggestions from the equipment suppliers.

The effectiveness of the measure varies in accordance with the magnitude of the change in vehicle size. Typical cost savings for downsizing cars are tabled below (Table 6.1); similar savings can be demonstrated for pick-up truck downsizing.

The savings can be calculated using only fuel consumption estimates. This method avoids the necessity of estimating maintenance cost changes which, typically, are difficult to predict. The best and most consistent source of fuel consumption estimates for light-duty cars and trucks is the Transport Canada "Fuel Consumption Guide". For heavy vehicles, dealer and user estimates must be used and will be less reliable.

For heavy trucks, the measure of effectiveness is the decrease in the net fuel consumed to provide the same service through fewer vehicle-kilometres (higher tonne-km/L). Operating costs of the heavy trucks do not increase substantially for larger payload capacities; for example, a 5-ton truck has a 66% increase in payload with only a 25% increase in direct fuel consumption compared to a 3-ton vehicle. Thus, the overall efficiency of the truck, when it is hauling material, can be increased and significant savings attained. Further, it can operate on longer routes (e.g., sanding), thus reducing the amount of deadheading to the depot for reloading.

Implementation Experience

One of the best examples of the effectiveness of this process has been the modification of the City of Ottawa's police fleet. Police departments have traditionally used large, high-powered vehicles. The justification is that the space is required for passenger-carrying capacity and for the comfort of the driver, while the speed is needed for pursuit. While these requirements do exist, they are not a factor for the entire fleet. With this stratified need in mind, the Ottawa Police and Works Departments were able to categorize the actual tasks performed by the police officers into a variety of vehicle-performance classifications. It was found that, when used for non-patrol purposes,

Table 6.1

Typical Reductions in Vehicle Operating Costs by Changing Vehicle Size

	New size			
Original size	Full size	Intermediate	Compact	Sub-compact
Full size	—	10–15%	20–30%	40–50%
Intermediate	Increase	—	15–25%	30–40%
Compact	Increase	Increase	—	20–30%
Sub-compact	Increase	Increase	Increase	—

the "full-sized" specification grossly oversized the vehicle. Furthermore, they were able to establish that the non-patrol functions (summons delivery, public relations, etc.) generally did not overlap with the patrol function on the same shift. Therefore, they were able to replace a portion (10-25% currently) of the fleet with sub-compact vehicles. At the same time, the review of the fleet made the police rethink the size and speed requirements of their present patrol cars. They are now considering specifying only the physical characteristics required: acceleration rate, top speed, front and rear hip and head room, etc. In this way, a manufacturer who can comply with the specifications can bid on the tender regardless of the exterior dimensions of the vehicle.

The same re-evaluation process has been carried out even more extensively with the City of Ottawa's general fleet; for the past two years, over 80% of the new passenger vehicles purchased (62 in total) have been sub-compacts. Already, this policy has reduced the per-vehicle costs on these new cars by 40%, and still higher savings are expected in the future. Although there was initial employee opposition to having to "squeeze" into the small cars, this negative attitude has reversed itself with the now-recognized ease of in-town manoeuvring and the decreased operational costs. Currently, the operating departments are requesting that sub-compact vehicles be ordered.

Summary

In summary, significant savings are possible through judicious selection of vehicle-size specifications. A simple re-evaluation at the time of every new-vehicle purchase will gradually develop a fleet which is attuned to the realities of high fuel prices.

2.6 Fuel-Saving Options and Devices

Objective

A vehicle's basic fuel efficiency can be increased through the judicious application of certain equipment options. These devices are normally best installed at the time of vehicle purchase but can, in some cases, be economical for retrofit to existing vehicles.

Description

Fuel savings are achieved by obtaining improvements in one or more of the following areas:

- decreased rolling resistance;
- decreased aerodynamic drag;
- increased engine efficiency;
- increased drivetrain efficiency;
- reduced vehicle weight.

The specific options include:

- *rolling*
  - radial tires
- *aerodynamic improvements*
  - air deflectors
  - truck box covers
  - aerodynamically smoothed roof-mounted lights
- *engine efficiency*
  - fuel type (see sections 2.2, 2.3)
  - improved lubricants
  - demand-activated auxiliary drive
  - thermostatically controlled fans and radiator shutters
  - speed governors
  - fuel-efficient engine models
- *drivetrain efficiency*
  - automatic or manual transmission
  - axle ratio
  - tag axle
- *vehicle weight*
  - light-weight truck boxes and plows

Effectiveness

A selection of the most frequently used options is considered in this section. Since they are all application-sensitive, information on other alternatives can best be obtained from suppliers and other operators. In the evaluation of the impact of these options, it is important to know how the vehicles are used. Specifically, the percentage of driving which occurs at speeds over 80 km/h is significant because the effectiveness of many options is speed-related (highway versus urban driving).

Radial tires can provide a saving of up to 5% over bias tires; however, in urban driving, this saving declines to closer to 2%. Further, the design of radial tires has, in the past, made them more prone to side-wall damage. For this reason, in urban applications where a lot of curb buffing is likely, radial tires provide little, if any, cost saving over bias tires for most vehicles. For vehicles such as patrol cars, however, the saving is generally viable and leads to low consumption and longer tire life.

Drag-reducing devices are effective only at speeds where drag is a significant portion of the total vehicle power requirement. Thus, in municipal fleets, because of the low-speed nature of the travel, the devices are of negligible use. One possible exception is the use of truck-box covers on light trucks. These covers will not only reduce drag but, more important, keep snow and ice out of the box in winter, thus making the vehicle lighter (lower energy requirement) and more accessible. It may also be possible to use air deflectors on some cube vans or delivery trucks if these are driven frequently on freeways or higher-speed roads (80 km/h). Finally, on police and emergency vehicles, care should be taken to avoid the use of large "light displays" because of the drag penalty these devices incur.

Improved engine lubricants (friction or viscosity-modified) can decrease a vehicle's fuel consumption by up to 5%. Viscosity-improved lubricants (0W or 5W-30) are particularly beneficial in cold weather, as they will decrease cold engine friction. The most significant problem to be faced in the use of specialty lubricants is the potential requirement for the storage and use of a variety of products. Since many fleets have just recently been able to rationalize lubricants to one or two for the whole fleet, there may be strong organizational pressures not to use specialty lubricants.

On heavy trucks and other maintenance equipment, the use of **demand-actuated auxiliary drives** can result in significant fuel savings. By avoiding the continuous operation of auxiliary devices (e.g., hydraulic pumps), the net power load on the engine can be decreased by up to 10%, with a resultant direct decrease in fuel consumption.

Thermostatically controlled radiator fans and shutters have been successful in reducing fuel consumption by up to 5% on trucks by reducing the amount of auxiliary power which is required for cooling, and by enabling the engine to reach normal operating temperatures more rapidly. Generally, these options are offered only on medium- and large-sized trucks at the present time. Where they are available, it is usually cost-effective to purchase them with the original vehicle. It is, however, usually not practical to retrofit them to an existing vehicle.

Selection of the most efficient **transmission and axle ratios** can reduce total fuel consumption. While the use of manual transmissions has historically been more efficient, most fleet operators have not measured any significant consumption difference between manual and automatic transmissions on late-model vehicles (especially trucks and large cars). This fact probably results from the inability of the drivers to actually achieve the theoretical difference. In fact, on a total-cost basis, the use of automatic transmissions on light- and heavy-duty vehicles has, in some cases, been less expensive because of the reduction in clutch-repair costs. The most advanced automatic transmissions use "lock-up" in high gear to decrease the hydraulic losses in the transmission. These "lock-up" transmissions should be specified wherever possible. Further, the specification of overdrive on manual transmissions should be restricted to those vehicles which are regularly driven at highway speeds. In all other cases, overdrive should be avoided as an unnecessary option for municipal vehicles. Considering the relatively low operating speeds of most municipal-fleet vehicles, low final drive ratios should also be specified to enhance fuel consumption.

Tag axles can be used to increase drivetrain efficiency and reduce vehicle capital cost. Fuel savings achievable by using a tag axle rather than driven axles are in the 0-5% range, depending upon the GVW class and duty cycle.

Finally, the reduction of **vehicle weight** (non-payload) is a basic goal at which to aim. This option entails not only the specification of lightweight bodies and accessories (e.g., aluminum snowplows), but also the continuous monitoring and removal of unnecessary weight from the vehicles (e.g., removal of ballast sand from snowplows). A good rule of thumb for light-duty vehicles is 1% savings for every 45 kg of weight removed. For larger vehicles, the sensitivity will be slightly lower.

In addition to the legitimate fuel saving options noted above, the fleet manager will frequently be approached by salesmen to purchase other **retrofit products**. Usually, these products claim to be capable of making the engine operate more efficiently through the use of a "newly formulated" fuel or oil additives. In general, these products are ineffective and should be avoided. The following items should be provided by people selling this kind of product:

- a list of users of the product;
- independent evaluation reports;
- an offer to demonstrate the product free of charge and to cover all damage liability.

In addition, it is worthwhile to contact the National Research Council, whose staff regularly evaluate new engine-related products. For information contact:

National Research Council
Fuels and Lubricants Laboratory
Montreal Road
Ottawa, Ontario
K1A 0R6
(613) 993-2415

Summary

There are a variety of equipment options available which can improve basic fuel efficiency by up to 5% when applied properly. Care must be taken to ensure that the vehicle's duty cycle is matched to the capabilities of the device so that maximum benefits are achieved. With this in mind, close liaison between user, purchaser, and supplier must be established to ensure proper specifications for the vehicle.

2.7 Vehicle Maintenance

Objective

The optimum fuel efficiency of municipal vehicles can be achieved by ensuring that they are well maintained mechanically. Further, there are indications that long-term operating costs are minimized by regular, high-quality maintenance.

Description and Effectiveness

The additional saving resulting from more frequent, high-quality maintenance is usually small because of the existence of regular inspection policies in most fleets. While the potential for reduction of engine-related malfunctions can go as high as 30% in vehicles that are in extremely poor condition, more typically, a tune-up at the recommended interval will result in less than a 2% improvement. Thus, although there are important benefits possible through a progression from low to normal levels of preventive maintenance, there are no significant savings in too-frequent inspection. Similarly, the lowest costs of vehicle operation are achieved at or near the manufacturer's recommended inspection schedule, as shown in Figure 6.5. Therefore, the fleet manager should establish a preventive maintenance system which requires vehicle inspection and replacement or adjustment of components at predefined time and usage points. This procedure will result in the lowest costs for both fuel and maintenance over the life of the vehicle. (Table 6.2 shows a typical report format used for scheduling vehicle maintenance.)

Figure 6.5
Trade-Off of Operating Costs to Level of Maintenance

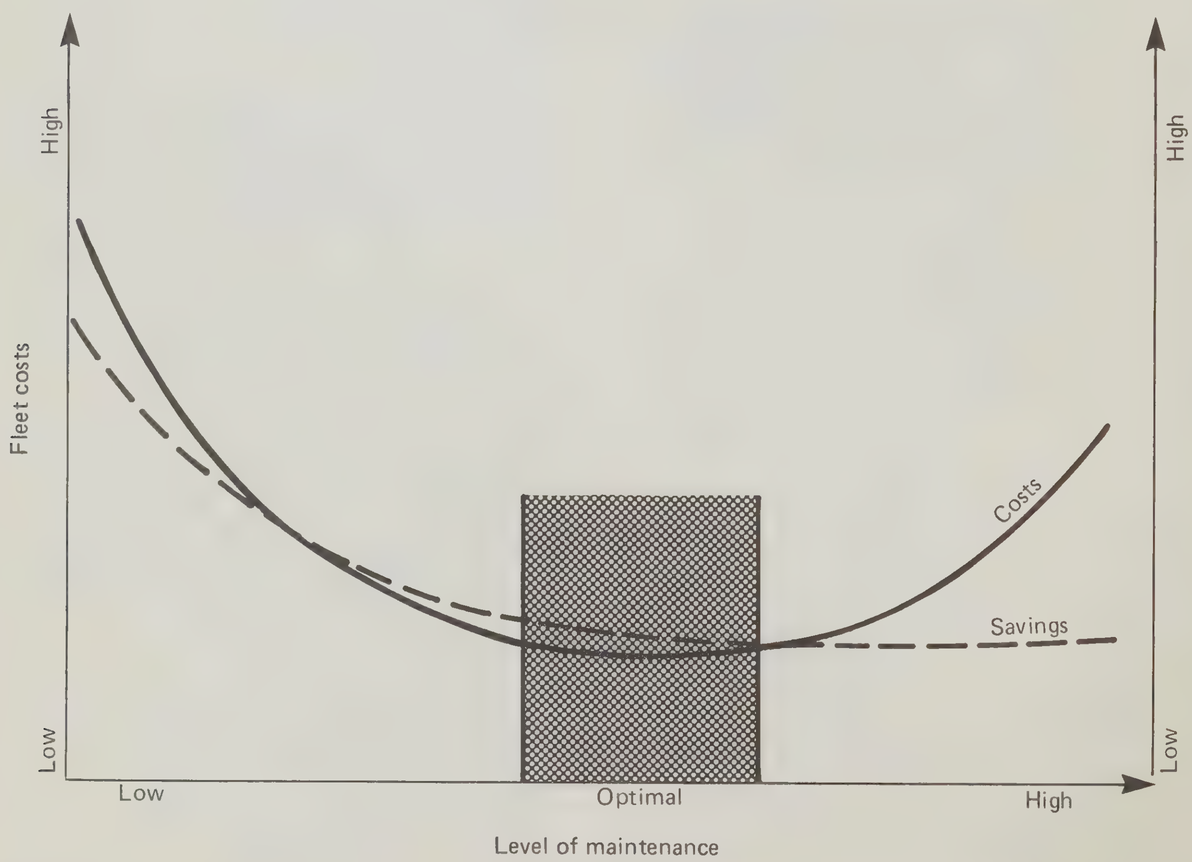


Table 6.2

Equipment Preventive Maintenance Checkpoint

Unit number and description	Chassis lube Now	Chassis lube Due	Lube/oil change Now	Lube/oil change Due	Tune-up Now	Tune-up Due	Brake inspection Now	Brake inspection Due	Winterizing deadline
Dunkirk									
0426 79 DGE D150, 6030GVW, pickup			314*	295					
0511 72 DGE D800, 27500GVW, dump			52	54					
City patrol									
0452 78 DGE D100, 6040GVW, pickup			200	200					
Thorold patrol 22									
0485 78 INT 1700, 28000GVW, RDS							654	606	
Thorold patrol 23									
0640 78 FD F350, 8200GVW, crew cab			205	79					
0698 78 FD F350, 8200GVW, crew cab			222	233					
Niedles yard									
0451 78 DGE D100, 6040GVW, pickup			200	200					
Niedles patrol 32									
0652 76 FD F800, 27500GVW, RDS			620	612					
Niedles patrol 33									
0488 77 FD F800, 27500GVW, dump					485	505			
Pelham patrol 42									
0639 78 FD F350, 8200GVW, crew cab			174	131					
0643 76 FD F804, 27500GVW, RDS					360	271			
0432 79 GMC TC7D042, 27500GVW, RDS/P					809	759			
Smithville yard									
0826 79 FD 555, 59 HP, tractor loader			115	68					
Smithville patrol 12									
0481 78 INT 1700, 28000GVW, RDS			434	440					
Beamsville patrol 13									
0692 78 FD F350, 8200GVW, crew cab			229	200					

SOURCE: Regional Niagara, Roadways Division, Management Information Systems. Data were recorded 24 February 1980.
*Data are odometer readings in hundreds of kilometres.

The most frequent engine adjustment errors can be corrected by checking and adjusting:

- idle air/fuel ratio,
- timing,
- idle speed,
- governor speed (where applicable).

Summary

Gains in fuel and cost conservation through improving the quality or frequency of vehicle inspection will be marginal, since this activity is usually already performed frequently enough.

2.8 Improved Vehicle Productivity

Objective

Within any fleet, there are opportunities to improve existing productivity. These improvements can result in:

- a reduction in the total number of vehicle-kilometres;
- use of more fuel-efficient vehicles and decreased use of fuel-inefficient ones;
- a reduction in unnecessary engine idling.

Description

Repetitive-route vehicles provide the greatest potential for fuel saving through operational improvements. Based on the fuel-use inventory for the municipality, the fleet energy conservation officer should attempt to rank the fleet according to its potential for routing optimization. This is best accomplished by first identifying those vehicles which are used in repetitive patterns (e.g., snowplows, garbage trucks, highway patrols, etc.). The use of these vehicles can then be individually reviewed, from the highest consumption group to the lowest.

The basic objective of the analysis is simple — to reduce the number of non-productive kilometres

and stops required. This is most effectively achieved by attempting to redesign routes so that the vehicle is deadheading as little as possible and avoids left-hand turns and numerous stop signs.

Effectiveness and Experience

In a **snowplowing operation**, in which the length of the route is determined by the fuel-tank capacity and shift-hours, the reduction in deadheading can be achieved by:

- routing the plow back to the depot on unplowed roads (or higher-level-of-service roads);
- having the vehicle refuel away from the home-base depot (at either municipal or retail outlets).

Typically, **garbage trucks** make up one of the largest fuel-use classes. Because much of their consumption is dependent upon routing, collection, and the location of land-fill sites, these are the elements which must be addressed for change. Some of the more typical improvement measures are:

- the use of several land-fill sites (decreases mean haul length);
- the leaving of any partially-filled truck at the depot overnight (eliminates drive to land-fill site);
- the use of two-sided street pickup where suitable.

Another large accumulator of kilometres is the **routine road patrol**. Most municipalities operate on a mixture of scheduled and complaint-induced patrols. Some have experimented with decreasing the level of inspection by decreasing the frequency of patrol and, thus, reducing vehicle use and fuel consumption. One example of this policy is provided by the Metro Toronto Roads and Traffic Department, who have eliminated over 50% of their patrol requirements through the adjustment of patrol frequency. Only a marginal decrease in the quality of the road network has occurred as a result of the program, as additional road status information has been obtained from non-patrol vehicles and complaint calls.

In conjunction with when and how a vehicle is used, fleet managers can affect fuel savings by attempting to **match the vehicle to the job**. Classic examples of vehicle mis-matches are:

- the use of dump trucks for crew movements;
- the specification of ¾-ton pick-up trucks when a ½-ton will handle the required payloads;
- the use of full-sized police cruisers for delivering summonses and for school public relations visits.

The capability of the fleet or operations manager to counter these mis-matches is dependent upon the size of the fleet and the aggressiveness of the manager. In small municipalities, the range of required missions which must be accomplished by one piece of equipment is large while the range of vehicle options is lower; therefore, the ability to "manage" is hampered. However, in larger fleets, the manager should attempt to reduce the size of the assigned truck (unless it is used for hauling material) to a minimum. This can best be accomplished by a motor pool arrangement where each user can be reassigned a vehicle according to immediate requirements, or by the rental of vehicles for special needs. The manager's operating assumption should be that a smaller vehicle could do the job — until it has been proven (e.g., load capacity or seat space exceeded) that the vehicle is too small.

It should be noted that these recommendations apply primarily to service vehicles. When assessing sizes of dump trucks, the operations manager should recognize that there is a trade-off reversal. As the load capacity goes up, so does the vehicle's energy efficiency (t-km/L) when loaded. Thus, the tendency should be to increase the size of sand/salt boxes, garbage trucks, dump boxes, etc., as a method of saving fuel through a reduction in the number of trips. The Regional Municipality of Ottawa-Carleton, for example, has increased the size of its sand-spreader boxes to 7.5 m^3, thus allowing longer routes with fewer non-productive kilometres. See Section 2.5 for a detailed discussion of vehicle sizing.

Finally, many municipalities are finding that the extensive use of **radio-dispatching** has reduced the need for non-productive trips and has improved operations co-ordination.

Summary

The continual review of operations, with the goal of increasing vehicle productivity can result in highly cost-effective changes. The program requires both a continuous incentive to improve and the application of common-sense management. In many cases this measure does not require capital expenditure to save fuel and thus is more attractive than capital-intensive conservation measures.

2.9 Driver Training

Objective

Optimal fuel consumption can only be achieved if drivers use fuel-efficient driving techniques. Consistency in the application of such techniques will probably require a driver-training program.

Description

Potentially, there are significant savings to be achieved through improving driver behaviour. This

instruction can be made part of the regular driver-safety training which all fleets should strive to offer. While specific training packages are just now being developed by the Transportation Energy Management Program (TEMP) staff and other concerned bodies, some core elements of instruction can be identified.

- Turn engine off when idling for more than 30 seconds (except in traffic).
- Avoid heavy accelerations or decelerations.
- Don't ride the clutch.
- Avoid speeds above 90 km/h.
- Plan your route to avoid major traffic-congestion areas.
- Plan your route to minimize the number of left-hand turns and stops.
- Check and adjust the tire inflation at least every month (daily for large trucks).
- Do a "walk around" on your vehicle to check for mechanical problems.
- Drive defensively and anticipate traffic situations.

It is important in a training program not only to provide drivers and mechanics with fuel-conservation knowledge, but also to encourage communication between vehicle users and maintenance personnel in order to identify problems early and thus save on fuel and repair costs.

Besides instructing them, an attempt should be made to monitor individual drivers whenever possible (e.g., through the use of tachographs or tracking of individual fuel consumption histories). Because of the diversity of work, monitoring the individual is not often possible. However, there will be some drivers who are assigned to specific vehicles (e.g., crew supervisors, social service workers). The performance (L/100 km) of these individuals can be monitored and the exceptional (either high or low) driver identified. Feedback to the driver regarding his fuel consumption can then be provided.

The simplest aspect of instruction (and the easiest to implement) is an "engine-off campaign". The program should encourage supervisory personnel to monitor employees for excessive engine idling and to distribute energy conservation material to drivers. This material should include the following information:

- The typical idle fuel flow in 15 minutes is sufficient for 4 kilometres of driving.
- The energy required to restart a vehicle is negligible compared to that required to idle the engine (usually less than 10 s worth of fuel).
- The vehicle's engine will not cool down quickly and should not be difficult to restart in cold weather (if starting is a problem, engine problems are indicated and should be repaired).
- Although the comfort of a nice warm interior is tempting, there is little need for continuous heating of the vehicle interior (it is better to run the engine only from time to time, as heat is needed).
- Incentives such as awards to conform to procedures should be used (e.g., T-shirts, hats, pins, etc.).
- The public image of municipal fleets should be emphasized. (The sight of prolonged idling of fleet vehicles provides a negative public image.)

Effectiveness

While some analysts have talked of fuel consumption improvements of up to 20% as a result of driver training, there has been no solid proof of this degree of improvement on a fleet-wide basis. A more legitimate expectation is probably a 2-5% fuel saving, given a well constructed and supported driver education and monitoring program.

Several major municipalities recently surveyed had, at one time or another, attempted an "engine-off" campaign. In no instance could the fleet manager ascertain the effectiveness of the program.

The fact that no effectiveness can be measured in the fuel consumption statistics does not discount the usefulness of an information program on the subject of unnecessary idling. It is very inexpensive to institute and, therefore, the economics of an "engine-off" program are usually good.

Implementation Experience

None of the municipalities recently contacted had implemented a full driver-training program, although virtually all of them had adopted an "engine-off" campaign or had had their vehicle-safety trainer initiate the expansion of the existing program to cover conservation.

Summary

Driver training can create a working climate which encourages conservation by providing the necessary knowledge and incentives to reduce fuel use. Savings of up to 5% are typical, with much higher savings possible in specific situations.

3 Analytical Techniques

3.1 Introduction

Anything that saves energy produces savings in direct fuel costs; but sometimes the conservation costs can outweigh the benefits. If one were to consider only energy conservation, there would be no limit to the amount of conservation that could be justified. However, each additional decrease in fuel consumption is harder or more costly to achieve than the previous one and, at some point, it does not make financial sense to invest further in conservation. Thus, because municipal operations are chronically restrained in resources, the good fleet manager must use decision-making techniques which will assure both energy and financial resource conservation.

There are basically two methods for dealing with investment analysis: Payback Period Analysis and Life-Cycle Costing. Both of the procedures are dependent upon access to accurate and consistent data not only from municipal fleet records, but also from equipment suppliers. Without such background information, none of the following analysis techniques will be an effective or accurate decision-making tool.

3.2 Payback Period

The "payback period" method of determining the investment attractiveness of the energy conservation measures focuses on the time required by the savings in energy costs to offset the original price premium. There are two approaches to calculating the payback period: one which assumes no fuel price increases or cost of money *(simple payback)*, and another which adjusts for increases in fuel costs and for the internal cost of money *(discounted payback)*.

The more correct method is the latter; however, the first method can be used to make a rough estimate of the payback period. If this rough estimate falls within the acceptable payback time (typically three to five years), then no further detailed analysis is required. However, if the outcome is marginal or even unacceptable, then a detailed analysis should be carried out, as the discounted payback period determined from the detailed analysis will frequently be shorter (more acceptable) than the "quick and dirty" calculation indicates. This shift in calculated payback period is due, in part, to the differential between the municipality's internal cost of money (e.g., 10-14% per annum) and the anticipated cost increase of fuel (e.g., 20-25% per annum). The setting of the limits of the acceptable payback period is generally related to the municipality's own policies, but should never exceed the expected vehicle service life.

In summary, simple payback period analysis applies the following algorithm:

$$\begin{aligned}\textit{payback period (in months)} &= \frac{\textit{initial cost premium}}{\textit{monthly cost savings}} \\ &= \frac{\textit{initial cost premium}}{\textit{(monthly fuel savings) (fuel cost)}}\end{aligned}$$

The advantages of this analysis are:

- minimal data requirement;
- assured cost recovery over a set period of time;
- straightforward presentation and comprehension;
- no requirement to estimate residual value of equipment.

It has the disadvantage of ignoring the effect of any costs or benefits occurring after the payback period.

3.3 Life-Cycle Costing

The life-cycle costing method compares the initial cost premium with future savings, after converting all dollar values to their present value. Thus, there is a consistent financial basis of comparison. This method includes consideration of rising fuel prices and the time value of money. It includes all costs and savings over the service-life of the vehicle, i.e., even those occurring after the payback period.

In summary, life-cycle costing compares the initial cost premium with the sum of the present value (discounted), costs, and savings resulting from the new vehicle. Its most significant drawback is the need for a long-term estimate of prices and interest rates, and an evaluation of the projected residual value of the vehicle at the end of the vehicle's expected life. These requirements increase the level of uncertainty of these calculations compared to the payback period analysis.

In order of increasing complexity and accuracy, the analytical techniques are:

- *Simple Payback Period Analysis* — assuming constant fuel prices and no cost of money;
- *Discounted Payback Period Analysis* — assuming rising fuel prices and a discount rate to account for the time value of money;
- *Life-Cycle Costing (Net Present Value)* — assuming rising fuel prices and a discount rate to calculate the current value of a measure.

See Tables 6.3, 6.4, and 6.5 for sample calculations for each of the analysis procedures. (See Appendix for blank work sheets.)

Table 6.3

Simple Payback Period Analysis Worksheet*

Required data

Replacement cost of present vehicle†($)	*18 000*	(1)
Price of new vehicle under consideration ($)	*22 000*	(2)
Present vehicle fuel consumption rate (L/100 km)	*76.0*	(3)
New vehicle fuel consumption rate (L/100 km)	*50.7*	(4)
Price of fuel used by present vehicle ($/L)	*0.41*	(5)
Price of fuel used by new vehicle ($/L)	*0.40*	(6)
Present vehicle use (km/month)	*675*	(7)
New vehicle use (km/month)	*675*	(8)
Present vehicle monthly maintenance costs ($)	*70*	(9)
New vehicle monthly maintenance costs ($)	*60*	(10)

Calculation procedure

	Present vehicle		New vehicle	
Vehicle purchase price ($)	*18 000*	(1)‡	*22 000*	(2)
Difference in purchase price ($)		*4000*	(a)	
Vehicle fuel consumption rate (L/100 km)	*76.0*	(3)	*50.7*	(4)
Cost of fuel ($/L)	X *0.41*	(5)	X *0.40*	(6)
Monthly use of vehicle (km/month)	X *675*	(7)	X *675*	(8)
	÷ 100 km		÷ 100 km	
Fuel cost per month ($)	= *210.33*		= *136.89*	
Maintenance cost per month ($)	+ *70*	(9)	+ *60*	(10)
Total direct cost per month ($)	= *280.33*		= *196.89*	
Difference in direct costs per month ($)		*83.44*	(b)	
Payback period (months) is a ÷ b		*47.9 (4 years)*		

*Assuming no increase in cost of money or fuel price

†The term 'or option' is implied wherever 'vehicle' is used

‡Numbers in parentheses refer to the input data originally defined

Table 6.4

Payback Period Analysis Worksheet*

Required data

Replacement cost of present vehicle†($)	18 000	(1)
Price of new vehicle under consideration ($)	22 000	(2)
Present vehicle fuel consumption rate (L/100 km)	76.0	(3)
New vehicle fuel consumption rate (L/100 km)	50.7	(4)
Price of fuel used by present vehicle ($/L)	0.41	(5)
Price of fuel used by new vehicle ($/L)	0.40	(6)
Present vehicle use (km/month)	675	(7)
New vehicle use (km/month)	675	(8)
Present vehicle annual maintenance costs ($)	840	(9)
New vehicle annual maintenance costs ($)	720	(10)
Discount rate, DR‡§	1.15	(11)
Fuel price growth rate, FR§	1.25	(12)
Maintenance cost growth rate, MR§	1.15	(13)

Calculation procedure

	Present vehicle			New vehicle	
Vehicle purchase price ($)	18 000	(1)#		22 000	(2)
Vehicle price differential, PD ($)			4000		
Vehicle fuel consumption (L/100 km)	76.0	(3)		50.7	(4)
Cost of fuel at time of vehicle purchase ($/L)	X 0.41	(5)		X 0.40	(6)
Monthly use of vehicle (km/month)	X 675	(7)		X 675	(8)
	÷100 km			÷100 km	
	X 12 months			X 12 months	
Fuel cost per annum ($)	= 2523.96			= 1642.68	
First year's fuel cost saving, FS ($)			881.28		
Maintenance cost per year ($)	840	(9)		720	(10)
First year's maintenance differential, MD ($)			120		

For each successive year, calculate:

1. The update PD, obtained by multiplying the previous year's PD by DR
2. The year's fuel cost saving, based on FS and FR
3. The year's maintenance cost saving, based on MD and MR
4. The year's direct cost saving, which is the fuel cost saving plus the maintenance cost saving
5. The cumulative direct cost saving.

The calculation is done year by year until the cumulative direct cost saving surpasses the updated vehicle price differential or until the expected vehicle service life is reached, whichever is soonest.

Begin by entering the values for FS and MD in the year 1 column. Add them together to obtain the year's direct cost saving. Obtain FS and MD for subsequent years by multiplying those of the previous year by the appropriate growth rate, FR and MR, respectively. Carry the year's cumulative cost saving to the next year's column. Work from left to right, completing each column and comparing its cumulative cost saving with the updated vehicle price differential for that year until cumulative saving exceeds updated price differential. At this point the payback period is reached.

This analysis can be repeated with different inputs, e.g., discount rate, rate of fuel price growth, to obtain an idea of the sensitivity of the payback period.

*Assuming an increase in fuel cost and opportunity cost of money

†The term 'or option' is implied wherever 'vehicle' is used

‡The municipality's cost of money may be used for the discount rate

§Write XY% as 1.XY

#Numbers in parentheses refer to the input data originally defined

Table 6.4 (continued)

Cost element	Year (period) 1	2	3	4	5
Fuel saving	FS = 881	X FR = 1101	X FR = 1377	X FR = 1721	X FR = 2151
Maintenance saving	MD = 120	X MR = 138	X MR = 159	X MR = 183	X MR = 210
Year's direct cost saving, FS + MD	1001	1239	1536	1904	2361
Cumulative cost saving					
Year 1	1001	1001			
Year 2		2240	2240		
Year 3			3776	3776	
Year 4				5680	5680
Year 5					8041
Updated vehicle price differential	PD = 4000	X DR = 4600	X DR = 5290	X DR = 6083	X DR = 6996
Payback period	= *4.4 years*				

Table 6.5

Life-Cycle Costing Worksheet

Required data

Replacement cost of present vehicle*($)	*18 000*	(1)
Price of new vehicle under consideration ($)	*22 000*	(2)
Present vehicle fuel consumption rate (L/100 km)	*76.0*	(3)
New vehicle fuel consumption rate (L/100 km)	*50.7*	(4)
Price of fuel used by present vehicle ($/L)	*0.41*	(5)
Price of fuel used by new vehicle ($/L)	*0.40*	(6)
Present vehicle use (km/month)	*675*	(7)
New vehicle use (km/month)	*675*	(8)
Present vehicle annual maintenance costs ($)	*840*	(9)
New vehicle annual maintenance costs ($)	*720*	(10)
Expected residual value of present vehicle at end of service life ($)	*8000*	(11)
Expected residual value of new vehicle at end of service life ($)	*9000*	(12)
Discount rate, DR†‡	*1.15*	(13)
Fuel price growth rate, FR‡	*1.25*	(14)
Maintenance cost growth rate, MR‡	*1.15*	(15)
Expected vehicle service life (years)	*5*	(16)

Calculation procedure

	Present vehicle			New vehicle	
Vehicle purchase price ($)	*18 000*	(1)		*22 000*	(2)
Difference in purchase price, PD ($)			*4000*		
Vehicle fuel consumption rate (L/100 km)	*76.0*	(3)		*50.7*	(4)
Cost of fuel at time of vehicle purchase ($/L)	X *0.41*	(5)		X *0.40*	(6)
Monthly use of vehicle (km/month)	X *675*	(7)		X *675*	(8)
	÷ 100 km			÷ 100 km	
	X 12 months			X 12 months	
Fuel cost per annum ($)	= *2523.96*			= *1642.68*	
First year's fuel cost saving, FS ($)			*881.28*		
Maintenance cost per year ($)	*840*	(9)		*720*	(10)
First year's maintenance differential, MD ($)			*120*		
Residual value at end of service life ($)	*8000*	(11)		*9000*	(12)
Residual value differential, RV ($)			*1000*		

The following algorithm includes consideration of the cost of money and rising prices for fuel and vehicle maintenance. It calculates the cash savings for each year over the life of the vehicle, discounts them with a user-selected discount rate, and compares their sum with the initial outlay.

If the sum of the discounted cash savings is greater than the vehicle price differential, the new vehicle is recommended.

The calculations follow four steps:

1. Calculating fuel and maintenance savings for each year
2. Dividing each year's savings by the appropriate discount rate
3. Summing the discounted savings
4. Comparing the sum with the vehicle price differential.

If the sum of discount savings is greater than the vehicle price differential, the new vehicle should be selected. If it is less, the new vehicle will not pay for itself during the normal service life.

*The term 'or option' is implied wherever 'vehicle' is used

†The municipality's cost of money can be used for the discount rate.

‡Write XY% as 1.XY.

Table 6.5 (continued)

Cost element	Year (period) 1	2	3	4	5
Fuel saving	FS = 881	X FR = 1101	X FR = 1377	X FR = 1721	X FR = 2125
Maintenance saving	MD = 120	X MR = 138	X MR = 158	X MR = 182	X MR = 209
Residual value differential, RV					1000
Year's cost saving, FS + MD + RV	1001	1239	1535	1903	3361
Discount rate, DR	÷ (1.15)	÷ $(1.15)^2$	÷ $(1.15)^3$	÷ $(1.15)^4$	÷ $(1.15)^5$
Yearly discounted saving	= 870	= 937	= 1009	= 1088	= 1671
Cumulative discounted saving	870	1870	2816	3904	5497
Original price difference, PD					– 4000
Net life-cycle saving					= 1497

4 Implementation Sequence

It is hoped that most municipalities will already have established a comprehensive energy management program. The application of energy conservation policies to the municipal fleet will then be a joint effort between the fleet manager and the conservation manager.

Among the conservation options of fleet management described in the preceding sections, there are some measures which logically should precede others. In developing this sequence, it is assumed that no previous energy management has been undertaken, but that the fleet is relatively well maintained. With these assumptions, the following implementation sequence is suggested.

Step 1: Fleet Inventory and Analysis

The first step is to develop a profile of the existing fleet by using the existing data base and estimates of any missing data. This profile should contain, by vehicle type:

- number of vehicles,
- annual use,
- annual fuel consumption and consumption rate,
- typical functions performed,
- average service-life.

This data should be analyzed to identify:

- the highest consumption groups,
- the groups with the highest vehicle turnover (shortest service-life).

These groups will be the most likely candidates for immediate action. The review process should also identify what record-keeping problems currently exist. All problems should be documented and plans should be made to modify the existing systems.

The forms and procedures discussed in Section 2.2 will be helpful in carrying out this step.

Step 2: Modification of New-Vehicle Specifications

Concentrating on the high-turnover vehicles, review the specifications for new vehicles and upgrade them to incorporate fuel efficiency considerations. Measures relating to fuel type, vehicle size, and options should be reflected in this step.

Evaluate the new equipment specifications using life-cycle costing to determine which changes are advisable. Particular attention should be paid to the potential for use of the following alternatives:

- downsizing,
- weight reduction,
- use of diesel engines, particularly for larger equipment and high-mileage vehicles,
- use of propane engines, particularly for pick-up trucks and automobiles,
- thermostatically controlled fans and radiator shutters,
- automatic or manual transmissions, depending on the axle ratio,
- demand hydraulics, and demand-actuated governors,
- radial tires,
- smaller engines,
- tag axle for smaller trucks.

Step 3: Driver-Training Program

Implement a driver-training program, stressing a reduction in idling, lower speeds, traffic anticipation, and proper braking. Consider an awards system to recognize drivers or groups who achieve the goals.

Step 4: Vehicle-Maintenance Program

Analyze the vehicle-maintenance program to determine whether changes can be made to save fuel. Ensure that reporting procedures are in place to enable operators to notify the shop if fuel-saving adjustments are needed. Stress should be on repairs to high idle speeds, dragging brakes, sticking chokes, and cold running engines. Provide block heaters for vehicles parked outside in cold weather.

Step 5: Current-Vehicle Upgrading

Carry out a review of each piece of equipment to ensure that any available cost-effective fuel-saving equipment has been installed. The items noted as being desirable considerations for new vehicle specifications make a good checklist, but cost will rule out a number of these on a retrofit basis.

Step 6: Vehicle Operations Review

In consultation with the operating group, evaluate the use of the vehicles to determine whether operating changes could save fuel. Routing changes and the use of two-way radios should be considered to reduce the distances travelled, and care should be exercised to ensure the use of the smallest and lightest vehicles possible.

Step 7: Fleet Monitoring

Monitor the fleet's performance (from an energy and cost perspective) on a continuous basis. This process will identify further actions to be taken. In addition, the data can be used as a reporting mechanism to senior management.

5 Sources of Information

5.1 Books

Energy Management in Municipal Vehicles. NTIS, PB80-190143, Massachusetts Department of Community Affairs: 1977.

Blackmore, P.R. *Fuel Economy of Gasoline Engines.* Thomas A. McMillan Ltd.; London: 1977.

Foster, W.S. *Handbook of Municipal Administration and Engineering.* McGraw-Hill Inc.

Minor, R.S. and W.B. Friedman. *Seventh Survey of Business Car Allowances, Controls and Fleet Management Practices.* Dartnell Corporation; Chicago, Ill.: 1978.

Motor Vehicle Fleet Management: Guidelines for Improvement of Equipment Acquisition, Maintenance, and Utilization Programs. American Public Works Association Special Report: October 1979.

Schneider, E.H. *How the Vehicle Maintenance Reporting Standards Help a Fleet.* Society of Automotive Engineers: 1978.

5.2 Periodicals

American Public Works. American Public Works Association; Chicago, Ill.: monthly.

Bus and Truck Transport. Maclean-Hunter Ltd.; Toronto, Ont.: monthly.

Canadian Driver/Owner. Maclean-Hunter Ltd.; Toronto, Ont.: quarterly.

Civic Public Works. Maclean-Hunter Ltd.; Toronto, Ont.: monthly.

Commercial Car Journal (for fleet management). Chilton Inc.; Radnor, PA: monthly.

Diesel Equipment Superintendent. Business Journals Inc.; Norwalk, Conn.: monthly.

Fleet Maintenance and Specifying. Irving Cloud Publishing Co.; Chicago, Ill.: monthly.

Fleet Owner. McGraw-Hill, Inc.; New York, N.Y.: monthly.

Fleet Owner: Small Fleet Edition. McGraw-Hill Inc.; New York, N.Y.: monthly.

Fleet Specialist. Chilton Inc.; Radnor, PA: bimonthly.

Heavy Construction News. Maclean-Hunter Ltd.; Toronto, Ont.: monthly.

National Association of Fleet Administrators Newsletter. NAFA; New York, N.Y.: monthly.

Motor Trucks. Wadham Publications Ltd.; Toronto, Ont.: monthly.

Truck Canada. Don Quick Publications; West Hills, Ont.: 9/yr.

5.3 Associations

American Public Works Association
1313 E 60th St.
Chicago, Ill.
60637

Automotive Transportation Service Superintendents' Association
2 Kastell Lane
Don Mills, Ont.
M3A 2Z1

Canadian Association of Fleet Supervisors
181 West 6th Ave.
Vancouver, B.C.
V5Y 1K3

Canadian Trucking Association
300-130 Albert St.
Ottawa, Ont.
K1P 5G4

Municipal Equipment Operators Association
c/o A. Baldry
Regional Municipality of Peel
10 Peel Centre Dr.
Brampton, Ont.
L6T 4B9

National Association of Fleet Administrators
295 Madison Ave.
New York, N.Y.
10017

Ontario Good Roads Association
Box 128, 354 Talbot St.
St. Thomas, Ontario
N5P 3T7

5.4 Seminars and Conferences

Canadian Fleet Management Seminar, sponsored by the *Automotive Transportation Service Superintendents' Association.*

CS Anderson Road School, sponsored by the *Ontario Good Roads Association.*

Appendix

Simple Payback Period Analysis Worksheet*

Required data

Replacement cost of present vehicle†($)	______	(1)
Price of new vehicle under consideration ($)	______	(2)
Present vehicle fuel consumption rate (L/100 km)	______	(3)
New vehicle fuel consumption rate (L/100 km)	______	(4)
Price of fuel used by present vehicle ($/L)	______	(5)
Price of fuel used by new vehicle ($/L)	______	(6)
Present vehicle use (km/month)	______	(7)
New vehicle use (km/month)	______	(8)
Present vehicle monthly maintenance costs ($)	______	(9)
New vehicle monthly maintenance costs ($)	______	(10)

Calculation procedure

	Present vehicle		New vehicle	
Vehicle purchase price ($)	______	(1)‡	______	(2)
Difference in purchase price ($)		______	(a)	
Vehicle fuel consumption (L/100 km)	______	(3)	______	(4)
Cost of fuel ($/L)	X ______	(5)	X ______	(6)
Monthly use of vehicle (km/month)	X ______	(7)	X ______	(8)
	÷ 100 km		÷ 100 km	
Fuel cost per month ($)	= ______		= ______	
Maintenance cost per month ($)	+ ______	(9)	+ ______	(10)
Total direct cost per month ($)	= ______		= ______	
Difference in direct costs per month ($)		______	(b)	
Payback period (months) is a ÷ b		______		

*Assuming no increase in cost of money or fuel price.
†The term 'or option' is implied wherever 'vehicle' is used.
‡Numbers in parentheses refer to the input data originally defined.

Life-Cycle Costing Worksheet

Required data

Replacement cost of present vehicle*($)	____________	(1)
Price of new vehicle under consideration ($)	____________	(2)
Present vehicle fuel consumption rate (L/100 km)	____________	(3)
New vehicle fuel consumption rate (L/100 km)	____________	(4)
Price of fuel used by present vehicle ($/L)	____________	(5)
Price of fuel used by new vehicle ($/L)	____________	(6)
Present vehicle use (km/month)	____________	(7)
New vehicle use (km/month)	____________	(8)
Present vehicle annual maintenance costs ($)	____________	(9)
New vehicle annual maintenance costs ($)	____________	(10)
Expected residual value of present vehicle at end of service life ($)	____________	(11)
Expected residual value of new vehicle at end of service life ($)	____________	(12)
Discount rate, DR†‡	____________	(13)
Fuel price growth rate, FR‡	____________	(14)
Maintenance cost growth rate, MR‡	____________	(15)
Expected vehicle service life (years)	____________	(16)

Calculation procedure

	Present vehicle			New vehicle	
Vehicle purchase price ($)	____________	(1)		____________	(2)
Difference in purchase price, PD ($)			____________		
Vehicle fuel consumption rate (L/100 km)	____________	(3)		____________	(4)
Cost of fuel at time of vehicle purchase ($/L)	X ____________	(5)		X ____________	(6)
Monthly use of vehicle (km/month)	X ____________	(7)		X ____________	(8)
	÷ 100 km			÷ 100 km	
	X 12 months			X 12 months	
Fuel cost per annum ($)	= ____________			= ____________	
First year's fuel cost saving, FS ($)			____________		
Maintenance cost per year ($)	____________	(9)		____________	(10)
First year's maintenance differential, MD ($)			____________		
Residual value at end of service life ($)	____________	(11)		____________	(12)
Residual value differential, RV ($)			____________		

The following algorithm includes consideration of the cost of money and rising prices for fuel and vehicle maintenance. It calculates the cash savings for each year over the life of the vehicle, discounts them with a user-selected discount rate, and compares their sum with the initial outlay.

If the sum of the discounted cash savings is greater than the vehicle price differential, the new vehicle is recommended.

The calculations follow four steps:

1. Calculating fuel and maintenance savings for each year
2. Dividing each year's savings by the appropriate discount rate
3. Summing the discounted savings
4. Comparing the sum with the vehicle price differential.

If the sum of discount savings is greater than the vehicle price differential, the new vehicle should be selected. If it is less, the new vehicle will not pay for itself during the normal service life.

Cost element	Year (period) 1	2	3	4	5
Fuel saving	FS = ______	X FR = ______	X FR = ______	X FR = ______	X FR = ______
Maintenance saving	MD = ______	X MR = ______	X MR = ______	X MR = ______	X MR = ______
Residual value differential, RV					______
Year's cost saving, FS + MD + RV	______	______	______	______	______
Discount rate, DR	÷ ( )	÷ ( )^2	÷ ( )^3	÷ ( )^4	÷ ( )^5
Yearly discounted saving	= ______	= ______	= ______	= ______	= ______
Cumulative discounted saving	______	______	______	______	______
Original price difference, PD					− ______
Net life-cycle saving					= ______

*The term 'or option' is implied wherever 'vehicle' is used
†The municipality's cost of money can be used for the discount rate
‡Write XY% as 1.XY.

Payback Period Analysis Worksheet*

Required data

Replacement cost of present vehicle†($)	______	(1)
Price of new vehicle under consideration ($)	______	(2)
Present vehicle fuel consumption rate (L/100 km)	______	(3)
New vehicle fuel consumption rate (L/100 km)	______	(4)
Price of fuel used by present vehicle ($/L)	______	(5)
Price of fuel used by new vehicle ($/L)	______	(6)
Present vehicle use (km/month)	______	(7)
New vehicle use (km/month)	______	(8)
Present vehicle annual maintenance costs ($)	______	(9)
New vehicle annual maintenance costs ($)	______	(10)
Discount rate, DR‡§	______	(11)
Fuel price growth rate, FR§	______	(12)
Maintenance cost growth rate, MR§	______	(13)

Calculation procedure

	Present vehicle	New vehicle
Vehicle purchase price ($)	______ (1)#	______ (2)
Vehicle price differential, PD ($)	______	
Vehicle fuel consumption (L/100 km)	______ (3)	______ (4)
Cost of fuel at time of vehicle purchase ($/L)	X ______ (5)	X ______ (6)
Monthly use of vehicle (km/month)	X ______ (7)	X ______ (8)
	÷ 100 km	÷ 100 km
	X 12 months	X 12 months
Fuel cost per annum ($)	= ______	= ______
First year's fuel cost saving, FS ($)	______	
Maintenance cost per year ($)	______ (9)	______ (10)
First year's maintenance differential, MD ($)	______	

For each successive year, calculate:

1. The update PD, obtained by multiplying the previous year's PD by DR
2. The year's fuel cost saving, based on FS and FR
3. The year's maintenance cost saving, based on MD and MR
4. The year's direct cost saving, which is the fuel cost saving plus the maintenance cost saving
5. The cumulative direct cost saving.

The calculation is done year by year until the cumulative direct cost saving surpasses the updated vehicle price differential or until the expected vehicle service life is reached, whichever is soonest.

Begin by entering the values for FS and MD in the year 1 column. Add them together to obtain the year's direct cost saving. Obtain FS and MD for subsequent years by multiplying those of the previous year by the appropriate growth rate, FR and MR, respectively. Carry the year's cumulative cost saving to the next year's column. Work from left to right, completing each column and comparing its cumulative cost saving with the updated vehicle price differential for that year until cumulative saving exceeds updated price differential. At this point the payback period is reached.

This analysis can be repeated with different inputs, e.g., discount rate, rate of fuel price growth, to obtain an idea of the sensitivity of the payback period.

Cost element	Year (period) 1		2		3		4		5	
Fuel saving	FS =	________	X FR =	________	X FR =	________	X FR =	________	X FR =	________
Maintenance saving	MD =	________	X MR =	________	X MR =	________	X MR –	________	X MR –	________
Year's direct cost saving, FS + MD		________		________		________		________		________
Cumulative cost saving										
Year 1		________		________						
Year 2				________		________				
Year 3						________		________		
Year 4								________		________
Year 5										________
Updated vehicle price differential	PD =	________	X DR =	________	X DR =	________	X DR =	________	X DR =	________
Payback period		?		?		?		?		?

*Assuming an increase in fuel cost and opportuinity cost of money.
†The term 'or option' is implied wherever 'vehicle' is used
‡The municipality's cost of money may be used for the discount rate
§Write XY% as 1.XY.
#Numbers in parentheses refer to the input data originally defined

Ontario

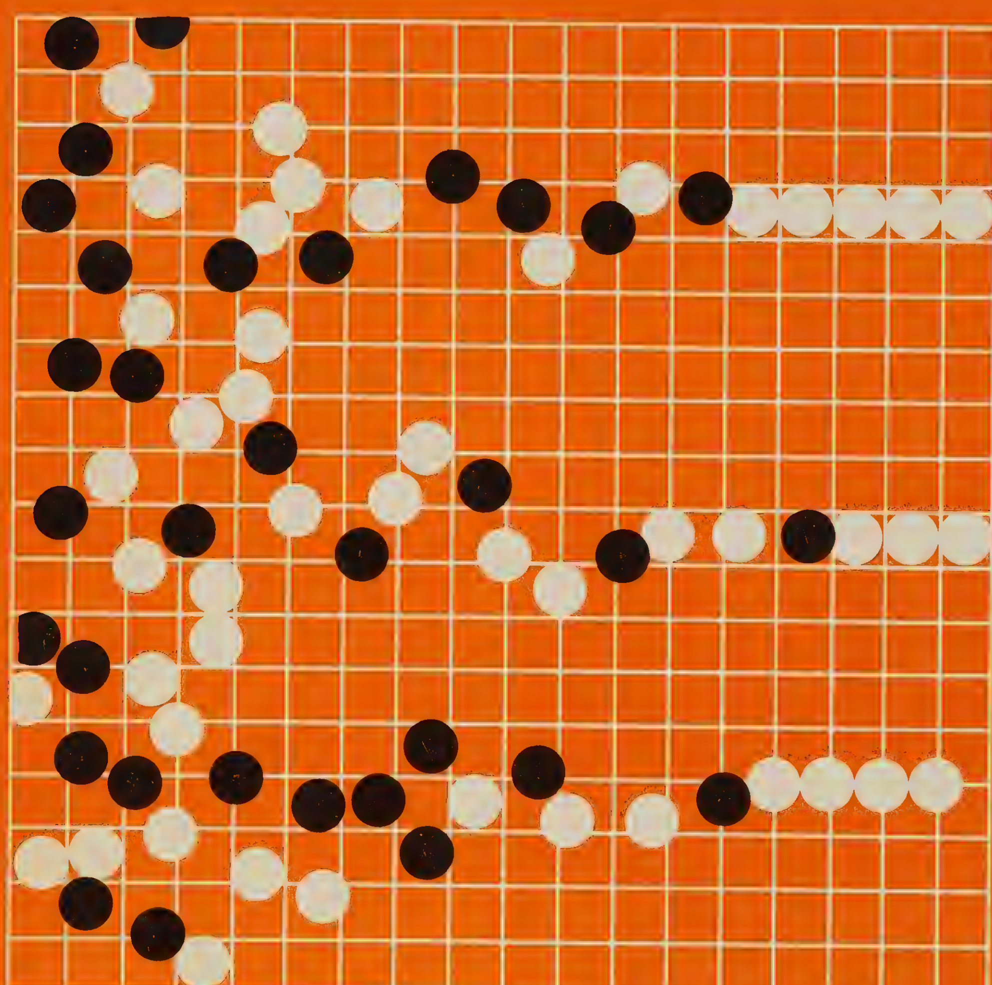
Ministry of Transportation and Communications
Hon. James W. Snow
Minister

Ministry of Energy
Hon. Robert Welch
Minister

Energy Ontario

Transportation Energy Analysis Manual

7: Road Construction and Maintenance



March, 1983

The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM

Transportation Energy Analysis Manual

7:
Road Construction and Maintenance

Published in Consultation with
The Municipal Transportation Energy Advisory Committee

by
The Transportation Energy Management Program (TEMP)
Transportation, Technology and Energy Division
Ontario Ministry of Transportation and Communications
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Preface

The purpose of the **Transportation Energy Analysis Manual (TEAM)** is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within the municipality. The Manual is organized into ten chapters, which outline the principal technical ways to conserve energy through transportation improvements.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is the crucial public-sector level because these decision-makers deal with the day-to-day activities of thousands of citizens residing within their municipalities. Energy conservation is an on-going, everyday affair, and the municipality is directly involved.

The **Transportation Energy Analysis Manual** consists of chapters on the subject areas listed below. These will be updated as considered necessary.

1. Overview and Summary
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Energy Program Management
10. Energy Analysis Methods

This chapter, **Road Construction and Maintenance**, investigates potential municipal energy conservation measures involving reductions in fuel consumption and the use of substitutes for oil-based materials used in road construction, as well as analytical techniques for estimating energy use.

Additional information on the Manual or any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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1 Introduction

Opportunities to conserve energy in municipal road construction and maintenance exist in three areas:

- **Reduction in Fuel Consumption in Road Construction and Maintenance**. This can be achieved by improving the fuel efficiency of the vehicles used, by providing driver training, and by reducing both the vehicle kilometres travelled and the hours of equipment use (e.g., air compressors).
- **Reduction in the Use of Asphalt Cement**. Asphalt cement is the residual product of refineries after fuel distillates and other fractions are removed from crude oil and is subject to the same market forces and tax policies as gasoline prices. Hence reductions in the use of such a material can make a significant contribution to energy and cost savings. Such reductions are achieved by the substitution of less energy-intensive material, by recycling, or by improved production methods.
- **Reduction in Geometric Design Standards**. Reductions in lane and shoulder widths reduce the amount of construction material required and hence result in energy savings. By contrast, a reduction in alignment standards reduces the amount of earthworks needed and the energy utilized in such operations.

The above areas were investigated for Ministry of Transportation and Communications (MTC) operations in 1978 in an attempt to estimate the potential energy savings associated with the various approaches [1]. The results of this study (with savings estimated for 1985) are indicated in Figure 7.1 and suggest that the potential energy savings in road construction greatly outweigh those in road maintenance. It is pointed out, however, that construction energy savings consist almost entirely of the energy content of materials, whereas maintenance energy savings consist of actual gasoline reductions. A wide range of assumptions were made in deriving the results of this study and although the findings relate to MTC operations, they do give an indication to municipalities of the relative effectiveness of various energy-conservation measures. The most promising measures and associated MTC policies are discussed below.

1.1 Road Construction

A reduction in geometric design standards seems to offer substantial savings. However, this measure could lead to adverse impacts on traffic safety and capacity if indiscriminately applied. In 1982, the MTC introduced a policy which would allow the use of lower design speeds on minor secondary highways and hence lead to more appropriate geometric design standards [21]. The opportunities for consideration of a similar approach to municipal roads appear to be limited to low-volume highways and residential streets.

Recycling asphalt concrete appears to be the most promising measure and, in fact, MTC introduced this technique in 1979. In the following three years, MTC laid over 2.2 million tonnes of recycled hot mix with associated cost savings of $12.5 million [2]. In order to provide Ontario municipalities with the most up-to-date information on all aspects of pavement recycling, MTC sponsored a major seminar on the topic in November 1981 [3].

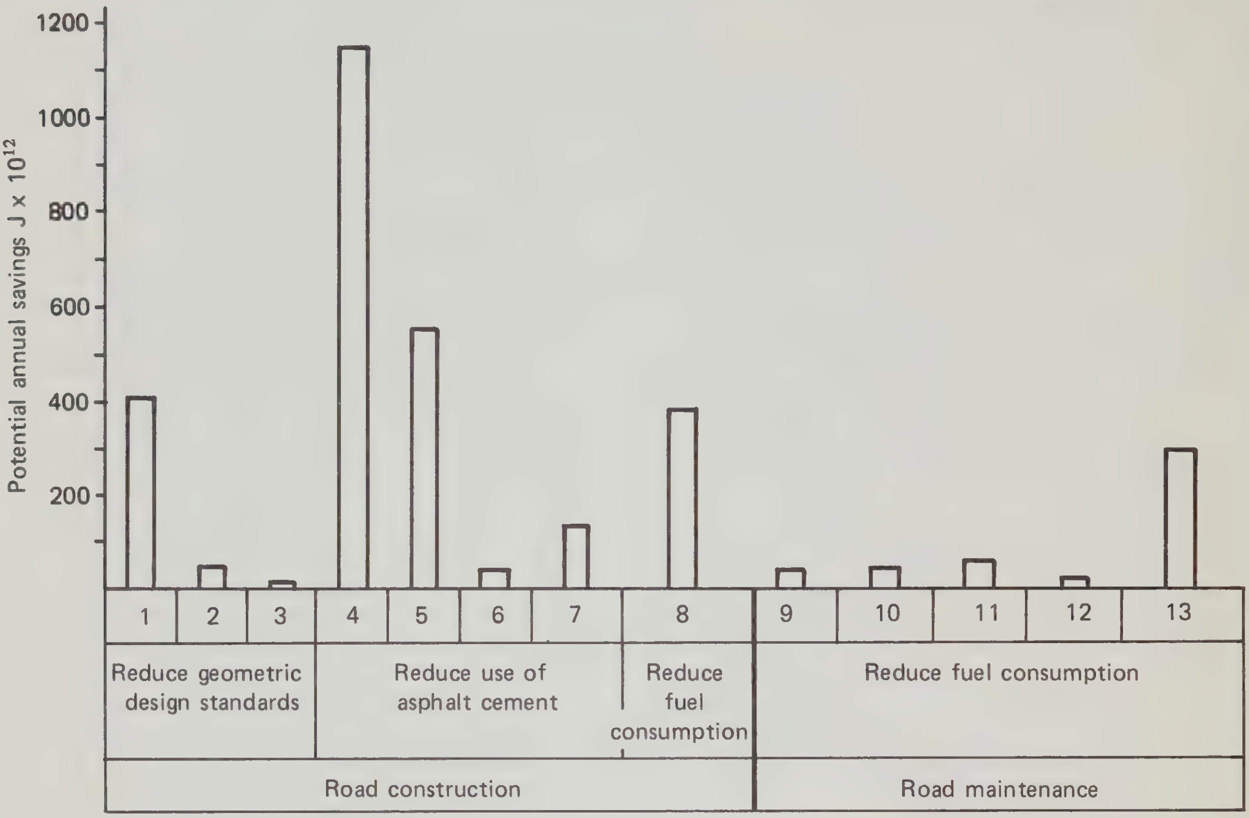
The potential energy savings due to the increased use of emulsion was recognized by MTC in 1981 when the option of using emulsified primer, instead of cutback asphalt, as a prime coat was introduced.

The advantages of asphalt binder substitutes are not considered sufficient to warrant major consideration in MTC operations at this time, although this situation may change in future depending on further research and the price of asphalt cement. Asphalt binder substitutes are, however, described in this report for those municipalities having a specific interest in the topic. Similarly, the improvement of asphalt concrete production and of contract organization, although applicable to the respective contractors, are also described.

In the original study [1], the use of paved shoulders, reduction in mass-haul distances, and the use of portland cement concrete were all investigated and found to result in minimal energy savings. As a result, these approaches are not considered in this report.

Figure 7.1

Potential Annual Energy Savings in MTC Operations (1985)



Key

1 — Lane width
2 — Shoulder width
3 — Alignment

4 — Recycle asphalt pavement
5 — Use asphalt binder substitute
6 — Increase use of emulsion
7 — Improve asphalt concrete production

8 — Improve contract organization

Key

9 — Patrol
10 — Snow ploughing
11 — Sanding and salting
12 — Roadside maintenance
13 — Fleet management

SOURCE: Opportunities for reduction in Petroleum Products Usage in MTC Operations. N.D. Lea and Associates, Toronto, July 1978.

1.2 Road Maintenance

Improved fleet management techniques (with an emphasis on driver training) appear to offer the greatest energy savings and, in fact, the Transportation Energy Management Program (TEMP) has recently (April 1983) completed the preparation of a municipal driver training program to conserve fuel [4]. In addition, a municipal fleet management demonstration project is under consideration for 1983.

Fuel savings in maintenance operations stemming from other measures (including the substitution of alternative less energy intensive measures and reductions in the level of service) do not seem to have the same impact as fleet management. Winter maintenance does have some potential in this regard and a study of possible fuel and cost savings in municipal winter maintenance activities is also under consideration by TEMP in 1983-84.

It is felt that the possibilities at this time for saving fuel in the area of road surface maintenance are minimal.

2 Road Construction Conservation Measures

2.1 Recycling of Asphalt Pavement

This measure is an alternative approach to the use of conventional materials for rehabilitation and maintenance of distressed pavements. As indicated in Figure 7.2, pavement recycling is one of many rehabilitation alternatives which the designer may select. The choice of an alternative depends on the pavement distress, the probable causes, economics, and design information.

The results of recycling projects undertaken during the past few years clearly indicate that the recycling of existing pavement surfaces is feasible and economic. Pavement materials that can be recycled include surfacing, base, and sub-base materials.

The options for pavement recycling are in-place and central-plant recycling.

In-Place Recycling

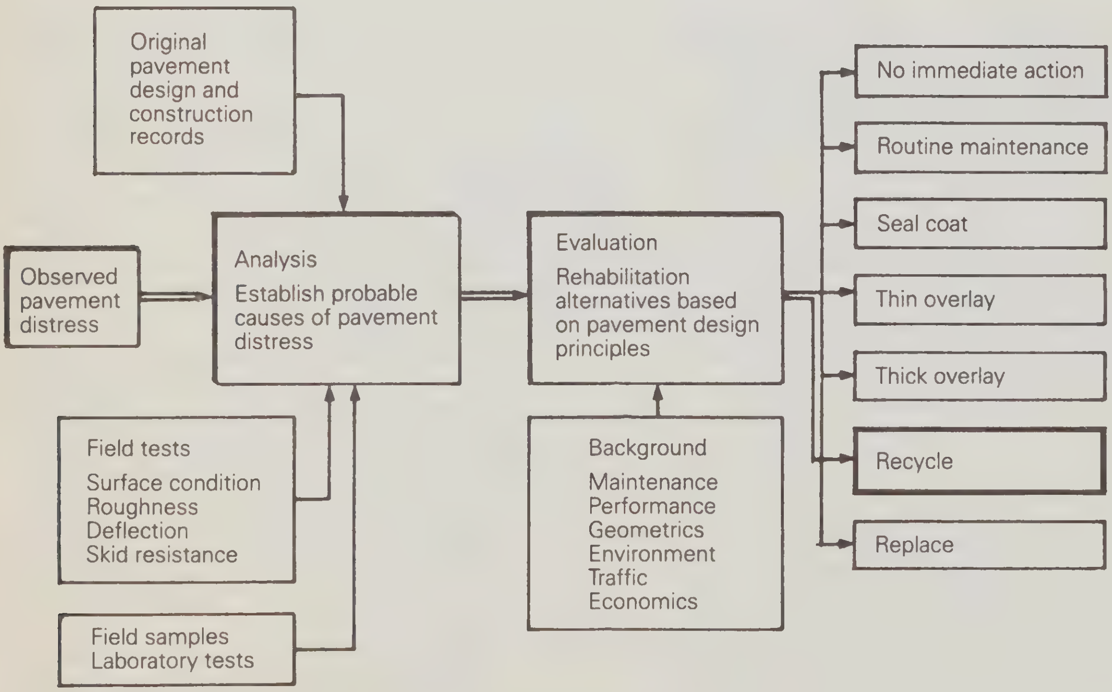
In-place recycling is not currently being undertaken by MTC. For municipalities interested in this option, however, a brief description follows [see also reference 3].

In-place recycling consists of either:

- reworking the surface of a pavement to a depth of less than about 25 mm by heater-planer, heater-scarifier, or cold-milling devices (usually a continuous, single-pass, multi-step process that may involve the use of new materials, including aggregate and / or modifiers); or
- in-place pulverization to a depth greater than 25

Figure 7.2

Analysis and Evaluation of Pavement Rehabilitation Alternatives



SOURCE: National Cooperative Highway Research Program. *Recycling Materials for Highways.* Synthesis of Highway Practice 54, Transportation Research Board: Washington, DC; 1978.

mm, followed by reshaping and compaction (performed with or without additional binder or stabilizer).

Central Plant Recycling

This method involves the scarification of the pavement material, removal of the pavement from the roadway prior to or after pulverization, processing of the material with or without the addition of a stabilizer or modifier, and laydown and compaction to the desired grade. It may involve the addition of heat, depending on the type of material recycled and the stabilizer used.

Central plant recycling techniques are different from other methods of recycling in that the material is removed from the roadway and mixed (either cold or hot) at a central location. Additional asphalt, recycling agents, cement, lime, aggregate, or other materials may be added at the plant to enhance the overall properties. Using central plants in the recycling of asphalt pavements is not a new concept; techniques that have been developed are shown in Figure 7.3.

Two approaches have been used to size the material prior to recycling in a central plant. The pavement can be reduced in size on site and then hauled to the central plant, or it can be removed from the site and crushed at the central plant. On-site or on-grade removal and sizing can be performed with cold-milling machines.

There are several advantages to central-plant operations. Excellent quality control can be obtained in terms of particle sizing, recycling-agent and binder content, blending percentages of new and recycled aggregate, and mixture homogeneity. Processes involving the use of heat generally produce mixtures that do not have to be cured in order to obtain near-maximum strength.

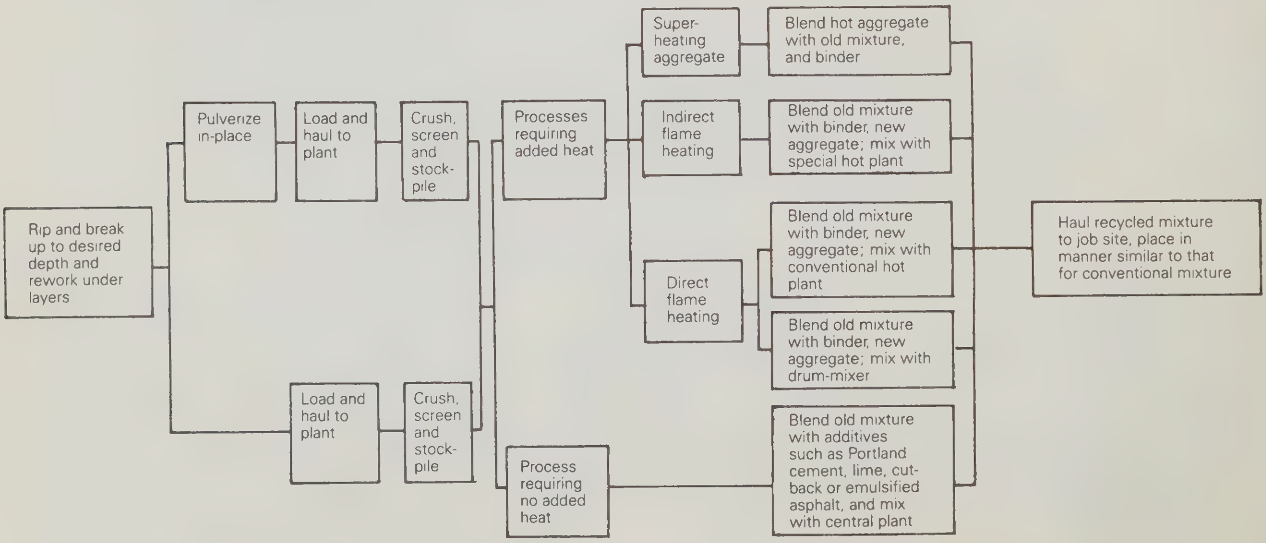
Selection of central-plant recycling operations over other recycling approaches will be most dependent on the availability of plant equipment, the need for structural improvement, and the distance of haul from the site to new aggregate sources and existing plants.

Effectiveness

The potential energy and cost savings of asphalt recycling are influenced by the following factors:

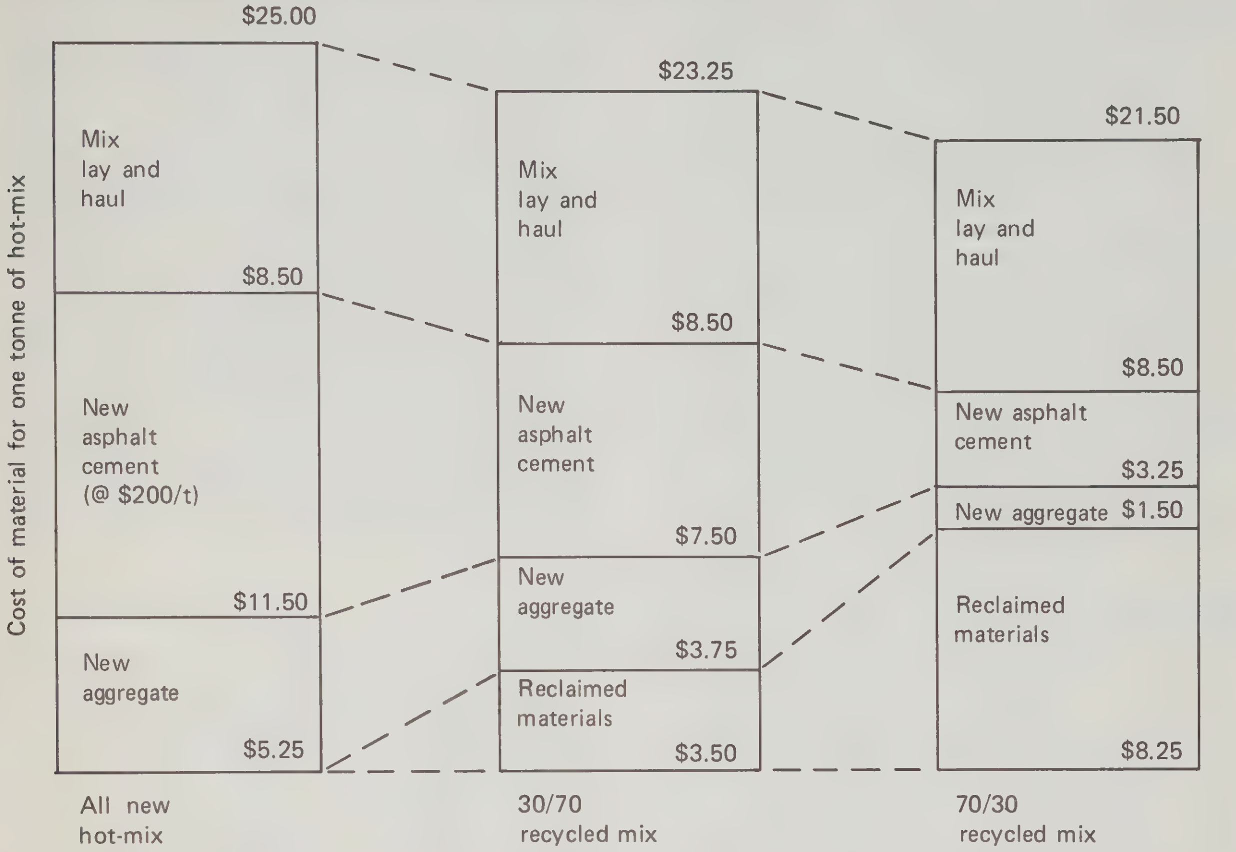
- amount of reclaimed pavement
- haul distance for virgin aggregate
- amount of new asphalt cement required
- haul distance for asphalt cement
- removal and crushing methods for pavement
- haul distances from the project to the nearest pavement disposal site and to the crushing/mixing plant
- type of mixing plant
- moisture content of the salvaged asphalt concrete and virgin aggregate.

Figure 7.3
Central Plant Recycling Techniques



SOURCE: Epps, J.A., D.N. Little, R.J. Holmgreen, and R.L. Terrel. *Guidelines for Recycling Pavement Materials.* National Cooperative Highway Research Program Report 224, Transportation Research Board, Washington, DC; 1980.

Figure 7.4
Cost Savings Through Asphalt Pavement Recycling



Source: W.A. Phang, *How to Save Energy and Reduce Costs — Asphalt Pavements.* Ontario Ministry of Transportation and Communications, Research and Development Branch. Paper to Ontario Good Roads Association. February 1983.

Typical cost savings in asphalt pavement recycling, indicated in Figure 7.4, are in the order of 7% for a 30/70 recycled mix and 14% for a 70/30 recycled mix. (The initial number refers to the percentage of reclaimed material, the second to the percentage of virgin material.) [3] Additional benefits of recycling include the correction of existing mix deficiencies and base problems; maintaining curb, inlet, and manhole elevations along with existing drainage patterns; and maintaining overhead structure clearances.

There are currently 28 hot-mix plants in Ontario equipped to undertake recycling. These consist of 17 pugmill plants (max. capability 50/50 recycled mix) and 11 drum-mix plants (max. capability 70/30 recycled mix) [3]. It is pointed out, however, that there are still a number of technical design and material improvements necessary to confirm the durability of mixes with contents of reclaimed materials in excess of 30%.

2.2 Use of Asphalt Binder Substitutes

Sulphur is the prime candidate for this substitution [5, 6, 7, 8]. Currently, the sulphur produced in Ontario as a result of desulphuring oil products is being used for other purposes. On the other hand, large quantities of surplus sulphur are produced in western Canada as a by-product of removing the sulphur from natural gas. Because sulphur is a by-product, no energy need be counted for its manufacture; however, the energy for its transport to Ontario must be fully considered.

Other possible substitutes for asphalt binder that can be considered for future use are organic materials from a renewable resource. Potential candidates, still in the research stage, are wood lignins and cellulosic materials [9].

Sulphur

Three specific uses for sulphur have been identified: in sand/asphalt/sulphur paving mixtures; as an asphalt cement extender; and, plasticized, as an independent binding agent. Sulphur melts at 116C and becomes very viscous at higher temperatures. Its viscosity is lowest at a temperature of 150°C. For best results, the mixing temperature for liquid sulphur should be maintained in the 120-150°C range. At higher temperatures, when mixed with asphalt cement, sulphur can

form hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), both of which constitute a health hazard.

A summary of the use of sulphur in asphalt mixtures is given in Table 7.1.

Sand / Asphalt / Sulphur — For approximately 15 years, sulphur has been studied by Shell Canada Ltd. as a means of upgrading poorly graded mineral aggregates. This process, which has been patented under the trade name of *Thermo-Pave*, has been tested on a number of full-scale pilot projects [5].

The Thermo-Pave mixture production requires plant modifications, as well as insulated hauling trucks to prevent freezing, which occurs at about 116°C (240°F). The mixture can be placed by using either forms or a modified paving machine. No compaction is required. Mechanical stability of the mixture is very high because the solidified sulphur, which fills the interstitial voids, becomes part of the aggregate structure.

More recently, the major emphasis in the Thermo-Pave process has been in the area of maintenance, by using what is known as *Thermo-Patch*.

Sulphur-Extended Asphalt (SEA) — The use of sulphur as a partial binder substitute for asphalt cement has been experimentally tested and reported to be feasible. Both Canada and France have actively studied and experimentally tested this concept with pilot projects, using the French Aquitaine, Gulf Canada, and SUDIC processes, respectively [5].

Plasticized Sulphur as a Pavement Binder — In the future it may be possible to use plasticized sulphur as an independent binder without asphalt. Experimental laboratory work indicates that the properties of elemental sulphur can be altered by means of commercially available plasticizers so as to produce a high-grade pavement binder material called *sulphlex* [8].

Table 7.1

Method for Using Sulphur in Asphalt Mixtures

Basic method	Example source	Features	Example field applications	Actual and possible limitations
Liquid sulphur addition to hot sand-asphalt mixes	Shell Canada Ltd	Use of marginal materials, i.e., unstable sands No compaction requirements	Richmond, B.C. 1970 Tilsonburg, Ont. 1972 Maclean, Sask. 1974 Sulphur, LA 1977	Special equipment, i.e., insulated trucks High quantities of sulphur Questionable economics except for special situations
	Société Nationale des Petroles d'Aquitaine	Potential economy Extension of asphalt supply Use of conventional paving equipment	Perimeter road of plant in Western France 1973 Lufkin, TX 1975	Storage, i.e., costs, formation of H_2S, and need for inert cover gas Need for additives to maintain storage stability Extra operators at plant Elemental sulphur vapor at paving site
Preblending of liquid sulphur and asphalt to produce SEA binder	Gulf Canada Ltd	Potential economy Extension of asphalt supply Use of conventional paving equipment Production of binder, on site, on demand No additives required	Alberta 1974, 1977 Ontario 1975, 1977, 1978, 1979 Michigan 1977, 1979 Holland 1978 Louisiana 1978 Florida 1979 Minnesota 1979	Extra operators at plant Elemental sulphur vapor at paving site
	SUDIC	Potential economy Extension of asphalt supply Use of conventional paving equipment Production of binder, on site, on demand	Alberta 1975, 1977 British Columbia 1979 Ontario 1982	Extra operators at plant Elemental sulphur vapor at paving site
Pugmill blending of liquid sulphur and asphalt to produce SEA binder	U.S. Bureau of Mines	Potential economy Extension of asphalt supply Use of conventional paving equipment No additives required	Nevada 1977	Elemental sulphur vapor at paving site Uniformity of dispersion Aggregate coating

SOURCE: Kennedy, T.W., and R. Haas, *Sulphur Asphalt Pavement Technology: A Review of Progress*. Transportation Research Record 741, Transportation Research Board, Washington, D.C.: 1980

Even more impressive than the successful laboratory production of a plasticized-sulphur binder is the discovery that by varying the percentages and combinations of plasticizers in the sulphur mixture, a binder can be developed that is as flexible as asphalt cement or as rigid as portland cement.

Wood Lignins

Lignin is the natural cement that binds fibres together in plants and trees. Lignin derivatives chemically extracted from wood are a major by-product of the papermaking industry. The three major chemical pulping methods are the sulphate (kraft), soda, and sulphite processes, which result in a spent liquor containing ligno-sulphate salts; this liquor is sometimes loosely called lignin.

While the properties of lignin in road surfacing are generally excellent, the effect produced, unfortunately, has a limited lifetime, owing to the gradual dissolution of lignin in water from both ground and surface run-off [9].

Cellulosic Materials

Cellulose is the most abundant renewable form of organic carbon in the world. Disposal of cellulosic wastes is expensive and often creates serious environmental problems, yet they represent a vast potential source of oils, tars, pitches, and various chemical intermediates. An on-going research effort is evaluating hydrolysis, pyrolysis, and hydrogenation as potential conversion processes for economically converting cellulosic wastes into a usable pavement binder [9]. The results of research to date indicate that the most promising method of producing highway binder from cellulosic wastes is by the dual process of pyrolysis and hydrogenation. The use of such materials hinges to a large extent on the future price of asphalt binders.

Effectiveness

The effectiveness of wood lignins and cellulosic materials has not yet been established. On the other hand, the behaviour of asphalt test roads in Ontario indicates that sulphur is a practical material to use in combination with asphalt cement both from a construction and a performance point of view [7]. Its usage will, however, depend on its price compared to that of asphalt cement.

Sulphur is currently a surplus material and its use in pavements has major advantages:

- It can be recycled in the same way as regular asphalt pavement [6].
- It may reduce cost. Asphalt cement prices may increase to over $200/tonne in Ontario in 1983, whereas sulphur prices are not expected to increase as rapidly.
- It provides design flexibility. Mixtures can be produced to satisfy, simultaneously, both low temperature cracking and higher temperature loading requirements.

It is possible, however, that sulphur may find other uses in industry as a substitute; in that case, it would lose its appeal as a paving material.

2.3 Increased Use of Emulsified Asphalt

The substitution of emulsion for cutback asphalt [10] has been identified as a possible energy saving measure. Examination of the energy required to produce emulsions and cutback asphalt, mix them with aggregate, and place them on the base course reveal that emulsions are substantially less energy-intensive than cutback asphalt. The primary factor accounting for this difference is the energy content of the solvents used to make the liquid asphalt [11]. With cutback asphalt, large quantities of petroleum distillates are evaporated into the atmosphere, thereby obviating their use for other purposes, such as heating or driving internal combustion engines. Conversely, emulsions have little, if any, solvents.

Overview

In MTC operations, cutback asphalt is only used for mulching and for prime coats (emulsion is used for all surface treatments). Mulching has been steadily decreasing over the last few years, owing to its high costs, to the point where it is only used in three MTC Districts: Bancroft, North Bay, and Kenora.

In 1980, an emulsified asphalt primer (EAP) was introduced as an alternative to cutback asphalt [12]. There are currently three approved materials for *prime coats*: MTC Primer, RC-30, and EAP. MTC Primer and RC-30 are solvent-based products (i.e., approx. 50% asphalt cement, 50% solvent), whereas EAP is a water- and solvent-based product (approx. 40% asphalt cement, 25% solvent, and 35% water).

Effectiveness

It is estimated that there is a potential energy saving of 30% when EAP is used. In addition, EAP has the following benefits in comparison with the other primers:

- A higher flash point which reduces the danger of fire (hence it is safer to handle);
- A faster curing time than MTC Primer;
- Less cover aggregate required;
- Good penetration (as good as other primers and usually faster);
- A less objectionable odour;
- Less inconvenience to the travelling public;

- Readily available from suppliers with little or no delay.

Guidelines to the choice of the most appropriate primer have been prepared by MTC [13].

2.4 Improved Production Process For Asphalt Concrete

Opportunities for increasing the energy efficiency of the asphalt concrete hot-mixing process lie in the increased use of drum mixing and in the improvement of procedures for heating and drying of aggregate.

Increased Use of Drum Mix Plant

Drum mixers are estimated to use considerably less energy than that required by other mixing plants [11]. MTC conducted an evaluation of drum mix plants during the period 1975-1977, concluding that their use was feasible and should be encouraged [14]. In the drum-mixer component of the production process, the aggregates enter the same end of the dryer as the burner flame and travel through the drum with the hot gases. At a point about half-way down, the asphalt is introduced into the drum and further drying of the aggregate, mixing, and coating take place.

One disadvantage of the drum mix plant is the segregation that sometimes occurs because of the method of operating the hot-mix storage silo. This segregation produces a very patchy surface appearance and, occasionally, the very open textures cause concern.

Improved Drying and Heating of Aggregates

It has been estimated that if the average moisture content of the aggregate going to the dryer (5%) can be reduced by as much as 1%, then about 10% of the fuel needed to heat and dry aggregate can be saved [15]. Possible methods for accomplishing this goal include:

- loading the cold-feed bins by picking up material from the outside edges of the stockpile where the driest aggregate is found — not at the base of the stockpile where water is draining from the top;
- leaving cold-bin gates slightly open when not in use, to allow water trapped in the cone of the bin to run out;
- turning over stockpiles to expose aggregate to the drying power of the sun and wind;
- providing covered storage for aggregate bins/stockpiles;
- having well-drained storage areas.

Effectiveness

Drum Mix Plant — In addition to energy savings, there are cost advantages to such plants over pugmill plants which have been suggested as being in the order of $1.10/t [16].

Drying and Heating of Aggregates — In addition to the 10% fuel savings mentioned earlier, it is estimated that a further 5% of the fuel needed to dry and heat the aggregate can be saved by properly maintaining the dryer so that the volume of air needed to heat the aggregate is at a minimum. Another 3% reduction in fuel consumption for heating aggregate can be achieved by reducing the stack temperature. (This can be done by rearranging the flights in the dryer to achieve a better veil, so that the stack temperatures are no more than 14°C above the aggregate discharge temperature.) Finally, a 2% reduction in the fuel requirements can be made through improving combustion of the fuel and air.

2.5 Improved Fuel Efficiency in Road Construction and Rehabilitation Operations

Overview

There are potential fuel savings in road construction and rehabilitation to be realized through the introduction of organizational changes and of driver training programs.

Detailed discussions in 1978 with Ontario contractors [1] concerning fuel efficiency indicated that they considered fuel as a minor portion of their costs (approximately 10%). Their more immediate concerns were the high costs associated with labour and vehicle maintenance. Based on the information derived from these discussions, the following approaches could be considered:

- Increasing the size of the individual construction contracts to allow for better equipment and personnel utilization.
- Requiring the contractor to prepare an energy-management plan to reduce overall consumption. As part of this plan, a strong emphasis would be placed on driver training.

Effectiveness

Potential savings for consolidated contracts are unknown. Firms have, however, achieved up to 50% savings by adopting energy-management programs and trucking firms have achieved up to 20% savings through driver training.

3 Road Maintenance Conservation Measures

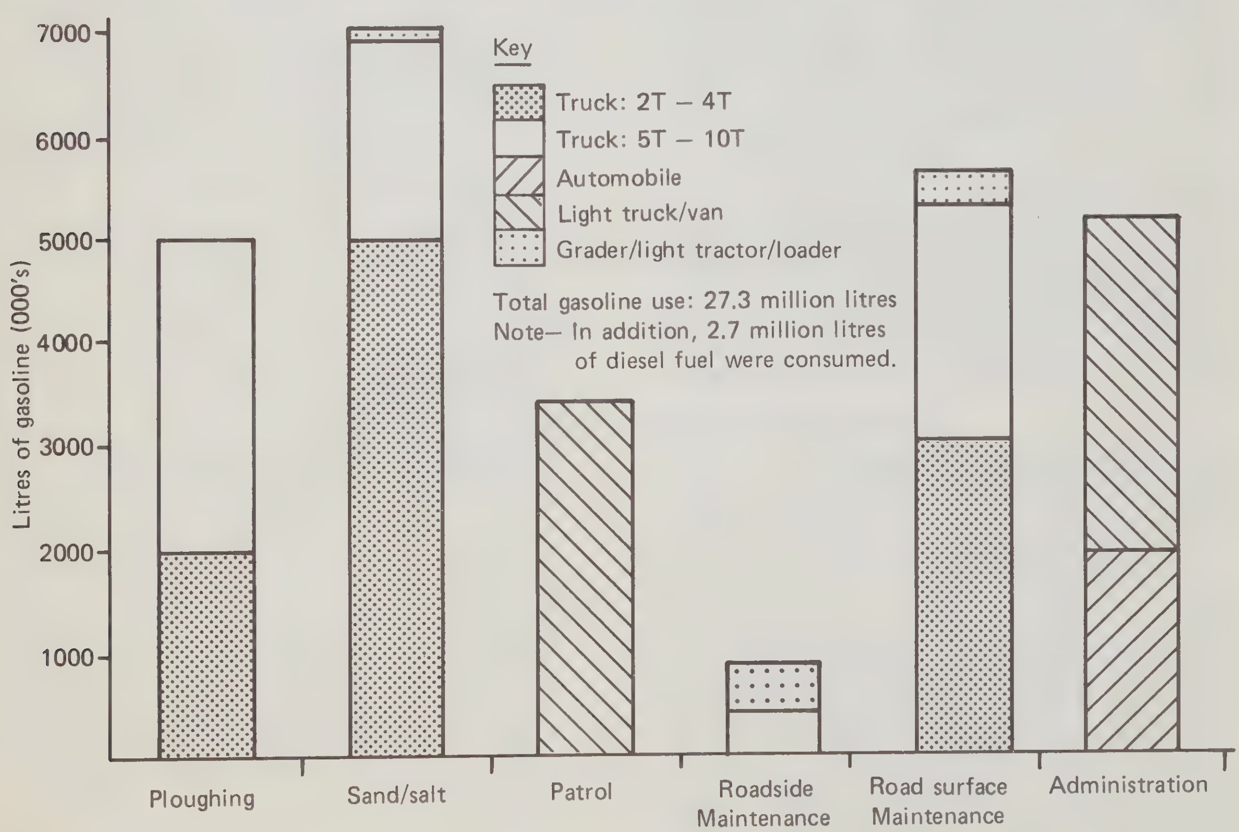
The major activities involved in road maintenance are considered to be inspection and patrol, ploughing, sanding and salting, roadside maintenance, road surface maintenance, and administration. For MTC operations, the vehicles involved and the fuel consumed annually are indicated in Figure 7.5 [1]. These statistics indicate that inspection and patrol and roadside maintenance together account for the lowest fuel usage (15%) while ploughing, sanding/salting, and road surface maintenance each consume from 20 to 25% of the total fuel usage. Administrative activities take up appoximately 20%. (It is not felt that sufficient fuel savings can be achieved in this area and hence it is not considered further.)

There are two approaches to the reduction of fuel consumption in road maintenance, that is, reducing the level of service provided and replacing existing practices by less energy intensive methods.

Reduction in the level of service in some outside maintenance activities (for instance, litter collection) has no direct effect on the fuel consumption of the road user. On the other hand, reductions in the level of service of other operations, particularly those connected with the road surface, may increase the fuel consumption of the road user as well as have an adverse effect on highway safety. Legal considerations must also be taken into account if reductions in levels of service are planned.

Figure 7.5

Annual Fuel Consumption in MTC Maintenance Operations by Equipment Type*



* For 1976

3.1 Inspection and Patrol

Overview

Procedures and problems encountered by municipalities in the inspection of roads vary greatly. Large rural municipalities have many kilometres of road to inspect in their maintenance operations, whereas urban areas have fewer kilometres but higher traffic volumes. The administrative organization of municipalities varies as well. Every effort should be made to optimize the timing of road inspections so that as many items as possible can be inspected during the same trip. Municipal staff from various departments (Works, Traffic, Parks) travel the municipal roads regularly. These people can report routine items requiring maintenance. Such reports will not replace detailed inspections or studies, but can save energy by allowing them to be cut back. Things like broken street signs or minor drainage problems can be readily identified in this way.

In 1978, tests were carried out by the MTC Thunder Bay District staff on the use of radio communication with trucking companies as a substitute for some patrolling of provincial highways. Numerous problems were encountered, including many derogatory remarks from truckers and false reports — the latter leading to a great deal of unnecessary driving to check the reports. Some success was achieved by restricting reports to a limited number of companies who had a large number of trucks on selected roads. However, the number of reports dwindled because the patrol radio was often unattended. At this time, C.B. radios are used by three patrols only.

Effectiveness

This will depend on the characteristics of the individual municipal operation. Potential fuel savings through reduced patrol frequency will require a detailed examination of current patrol standards to determine how much of a reduction is feasible and at what cost in terms of a reduced level of service.

3.2 Winter Maintenance

Winter maintenance activities consist of sanding and salting, and snowploughing.

Sanding and Salting

The costs involved in and the energy consumed by this activity vary among municipalities. Operating procedures usually contain specifications for sanding and salting operations for different levels of service. Frequency and timing of these operations is dependent upon the temperature range, type of precipitation, and road conditions, and on whether the temperature is rising or falling. Salt is considered indispensible in preventing traffic accidents and permitting acceptable traffic flow. Salt does, however, contribute significantly to the corrosion of motor vehicles and bridge decks, to pavement deterioration and, to a lesser extent, to pollution of the natural environment. The latter factor has led several municipalities to reduce the amount of salt used.

A recent study of the use of salt in MTC operations found that the standard salting rate was a good average rate, but that it should be flexible to suit different weather conditions [17]. The study concluded that salt use could be reduced by standardization, close adherence to the guidelines suggested, and a slight reduction in the level of service.

In addition, a reduction in the amount of sanding would reduce the amount of spring roadway cleaning.

Snowploughing

Instructions for snowploughing, specific to the classes of municipal roads, are given in municipal operating procedures. As in cases of sanding and salting, the actual frequency of snowploughing at the beginning of, during, and after a storm varies according to temperature range, type of precipitation, road conditions, and whether the temperature is rising or falling. MTC standards require that roads designated for bare pavement and centre-bare pavement should be ploughed at the beginning of a storm after 2 cm of snow has accumulated. During a storm, ploughing should proceed continuously so that snow accumulation does not exceed 2.5 cm for bare, 5 cm for centre-bare, and 7 cm for snowpacked pavement. A ploughing clean-up is required after the storm.

Reductions in the level of snowploughing will increase the fuel consumption of the user [18], have an adverse impact on safety, and may lead to legal action. More appropriate actions to reduce fuel consumption appear to be the utilization of fuel-efficient equipment and the adoption of fuel-efficient procedures follows.

- *Snowploughs*. Ploughs should be used wherever possible instead of snow blowers, which are not only expensive but energy intensive (450 L fuel/hour). In addition, extra-wide snow blades and snow wings can be used to reduce the number of passes on wide roads.
- *Sideslopes*. Deep snow accumulation in highway cuts can make snow ploughing ineffective and require the use of snowblowers. To remedy this situation, the MTC Stratford District staff have regraded side slopes from 2:1 to 6:1, thus allowing the wind to keep the highway clear of drifting snow [18].
- *Snow fences*. An innovation used by the MTC Owen Sound District staff is the 2.4m snow

fence which retains four times as much snow as a standard 1.2m fence, and hence reduces snowploughing. (An initial 1.2m snow fence is installed on long posts. When snow has reached the top, a second 1.2m fence is place above the first.) Lightweight plastic fences can be used instead of wooden ones. Such fences are lighter and only one-third of the volume of the wooden ones, hence only one-third of the installation and removal trips are required [19].

The preceding measures are primarily applicable to large rural municipalities. Urban municipalities can also save energy and cost in snow removal operations. By-laws prohibiting parking on snow routes improve the efficiency of ploughing. Policies for the towing away of abandoned cars, at the owner's expense, have a similar effect.

Effectiveness

No data are available on effectiveness, which of course will vary with each municipality. The results of the proposed 1983-84 TEMP winter maintenance study should provide invaluable information.

3.3 Summer Maintenance

Summer maintenance activities include roadside maintenance and road surface maintenance.

Roadside Maintenance

Some tasks, such as re-lamping and repairing of electrical traffic control devices, must be attended to as soon as possible because of the traffic safety hazard that is created by their failure. Other tasks, however, such as vegetation and litter control, have a lesser impact on road users. Therefore, some consideration could be given to reducing the level of such service activities as vegetation control, grass cutting, litter control, and summer maintenance of roadside areas. Smaller savings could also be made by deferring the repair of some roadside installations (such as guard rails, signs, fences, culverts, and other drainage items) or such tasks as painting and cleaning, until the needs along a particular stretch of road are of sufficient magnitude to minimize the use of maintenance vehicles for driving to the site.

Some roadside maintenance could be undertaken jointly with or coordinated between different municipal departments (for example, grass cutting between the Works and Parks departments or litter control between the Sanitation and Works departments). The cost and energy economy possible through such coordination would depend on the administrative organization and staff of the municipality.

Road Surface Maintenance

Although road surface maintenance may account for about a quarter of the total energy required for road maintenance in a municipality, decreasing such maintenance has negative effects. As the road surface deteriorates, fuel consumption of the vehicles travelling on it increases. In terms of the total energy consumed in the maintenance and use of the road, increased user fuel-consumption may, in the long run, be greater than the energy savings achievable through decreasing the level of road surface maintenance. The safety of the roadway also decreases as the level of maintenance of the road surface and its shoulders is allowed to decline. Increased accident costs may outweigh any savings in maintenance. Thus, it is unlikely that there is any potential for energy savings in reducing the level of road surface maintenance. As indicated earlier, there are, however, opportunities for the use of less energy intensive materials in maintenance activities. In addition, some fuel savings could be achieved by adopting effective patching techniques to ensure durable repairs, thus reducing repair frequency.

Effectiveness

As indicated above, the potential for energy savings in summer maintenance operations is restricted to reducing the frequency of roadside maintenance. In MTC operations this activity only consumed about 4% of the total fuel used in maintenance activities. Hence it is felt that any savings would be relatively small.

3.4 Maintenance Fleet Management

Effective fleet management measures offer significant and highly visible savings for any municipality. Such measures have already been dealt with in Chapter 6 of this Manual. They are summarized below, however, so they can be viewed in context with other maintenance measures.

Individual Measures

- *Energy Use Reporting.* Municipal fleet managers need to establish a reporting system that isolates fuel use from overall costs. It is necessary to know how the fuel is used, what energy reductions have been achieved, and which vehicles are high energy users.
- *Dieselization.* Diesel engines are not only more efficient than gasoline engines, but have longer operating lives and require less maintenance.
- *Alternative Fuels.* Propane is currently the most viable fuel; it costs less and provides maintenance savings. Larger fleets will benefit most from propane, as fixed costs can be spread over more vehicles.

- *New Vehicle Resizing*. As each vehicle in the fleet comes due for replacement, it can be evaluated to determine whether its capacity has been underused or overtaxed and the most appropriate size can be chosen.
- *Fuel Savings Options and Devices*. For optimal cost savings such items need to be installed at the time of purchase. They include radial tires, thermostatically controlled radiator fans, and shutters.
- *Vehicle Maintenance*. Municipal vehicles must undergo maintenance at regular intervals, preferably according to the schedules suggested by the manufacturer.
- *Improved Vehicle Productivity*. Such measures include route planning, matching vehicles to the job, and the use of radio dispatching.
- *Driver Training*. Aspects of such a program include instructing drivers in cost-saving driving practices; encouraging communication between drivers and maintenance personnel; and monitoring the fuel consumption of individual drivers.

Effectiveness

Fleet management measures have been recognized as having the highest potential for energy savings in MTC maintenance operations [1]. Numerous municipalities have already adopted one or more of such measures and realized substantial fuel savings (in some cases over 35% savings in fuel consumption on conversion of vehicles to diesel.)

As indicated earlier, TEMP has recently (April 1983) completed the development of a municipal driver-training program and is considering a fleet management demonstration project in an Ontario municipality later in 1983.

4 Analytical Techniques

In order to assess the energy impacts of road construction projects both direct energy consumption (that is, energy consumed directly for movement) and indirect energy consumption (in vehicle manufacture, road construction, and road maintenance) need to be considered. This approach has been adopted in considerable detail in the recent study of transportation energy in Metropolitan Toronto [20] and the following paragraphs, tables, and figures are based on this study.

4.1 Direct Energy Consumption

Automobile Energy Consumption

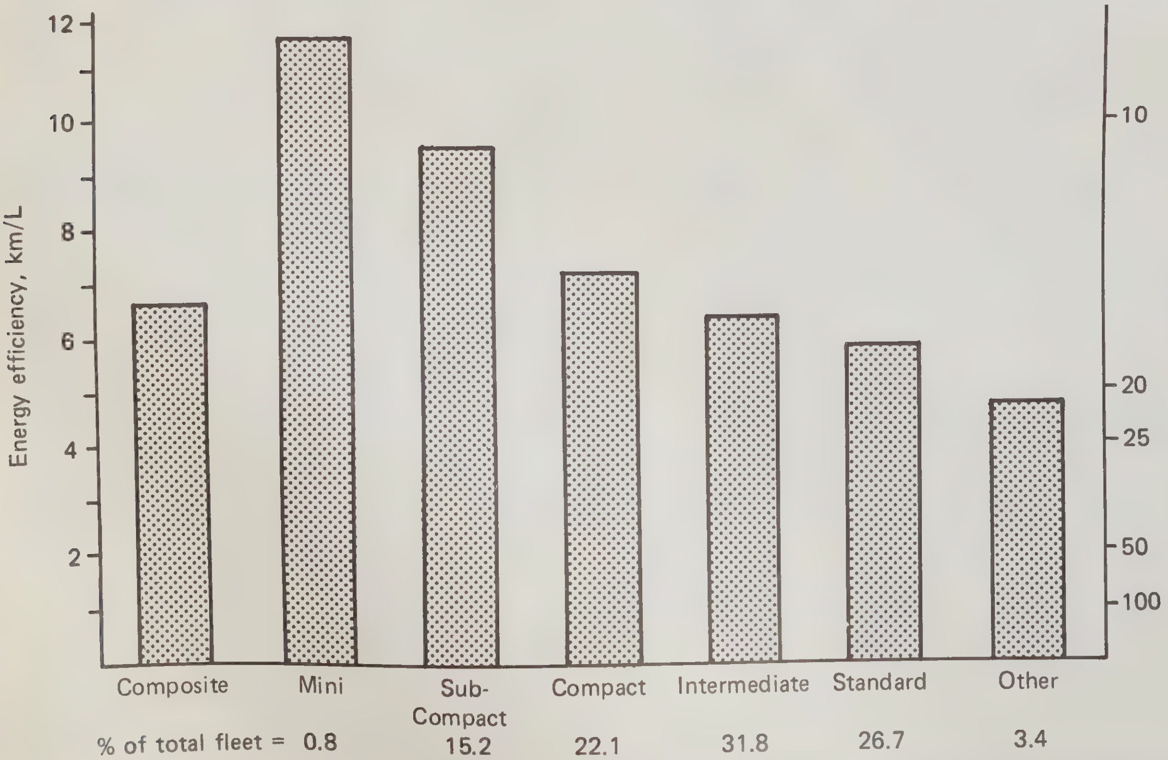
The numerous factors that influence automobile energy consumption fall under three broad categories: vehicle and highway characteristics, and characteristics of use.

Vehicle Characteristics — With the advent of legislation in the United States regarding automobile fuel economy, growing attention is being given to consumption by model year. Fuel efficiency in 1985, measured in litres per kilometre, is to be more than double the 1976 figure. In terms of smaller vehicles, the number of new-car registrations in Ontario has moved steadily towards lighter cars (in 1978, compact and subcompact cars accounted for 51% of all new-car registrations). In addition, manufacturers have, over the last few years, consistently downsized models to the extent that future curb weights are intended to be 20% lighter than previous levels.

The fuel efficiencies of different-sized cars in the Toronto area in 1978 are indicated in Figure 7.6. It is noted that between the Mini Class (1010 kg) and the Standard Class (2020 kg) the weight is doubled and the fuel efficiency halved. The effects of optional equipment are indicated in Figure 7.7. The V-8 engine has the greatest detrimental effect on overall fuel efficiency (-18.5%).

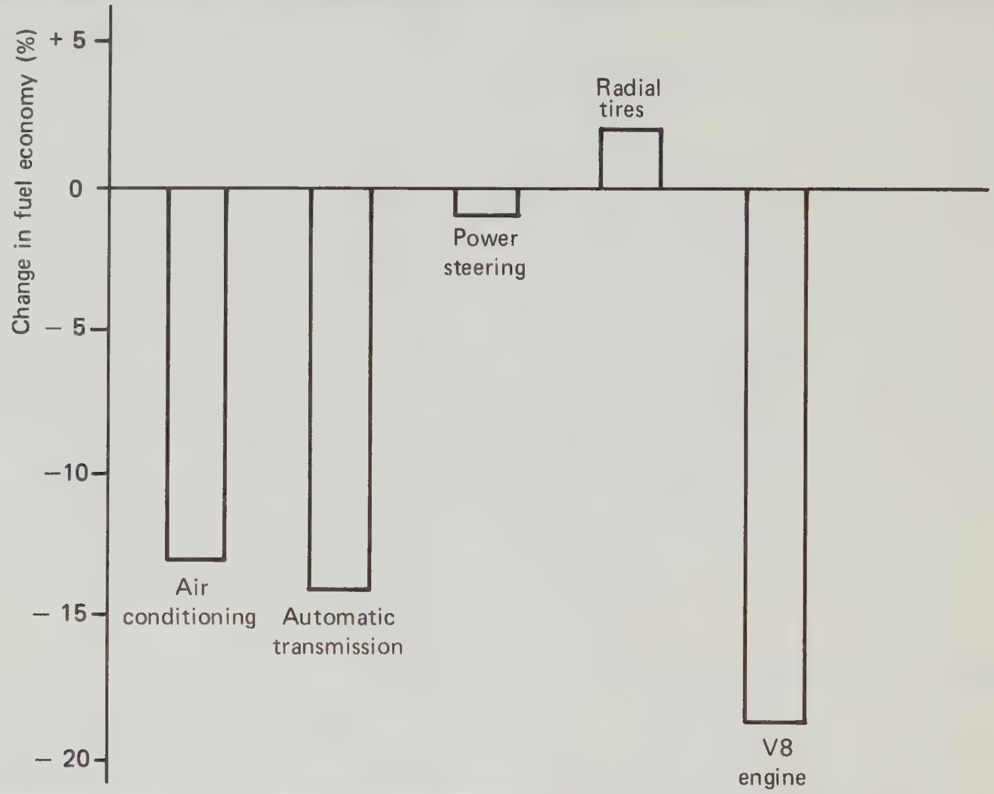
Figure 7.6

Fuel Economy Performance — Toronto Automobile Fleet



SOURCE: Ontario Ministry of Transportation and Communications

Figure 7.7
Energy Use Effects of Popular Options on 1978 Six-Cylinder Automobile



SOURCE: A.B. Rose, "The Energy Intensity and Related Parameters of Selected Passenger Transport Modes," Oak Ridges National Laboratories, ORNL 5506, U.S. DOE 1979.

Highway Characteristics — Fuel consumption depends on speed, degree of curve, gradient, quality of road surface, number of stops per kilometre, and traffic volume. Some of the more significant effects of the aforementioned factors are as follows (detailed tables of the effect of highway characteristics on fuel consumption are given in the Appendix).

- The lowest overall fuel consumption (10.5 L/100 km) has been achieved at a constant speed of 50 km/h.
- At a constant speed of 80 km/h, fuel consumption increases by 100% as the grade increases from 1 to 7%, and reduces by 54% as the grade decreases from 1 to 7%.
- At a constant speed of 80 km/h, a vehicle travelling on a gravel surface will consume 70% more fuel than if it were travelling on an asphalt surface.
- The fuel consumed when vehicles are idling in traffic or at a signal varies from 1.28 L/h (4 cylinders) to 2.31 L/h (8 cylinders).
- On a 6-lane urban street (no parking) the introduction of 1 stop/km increases fuel consumption by 58%.
- On a 6-lane urban street (with parking) the introduction of 1 stop/km increases fuel consumption by 37-50% (depending on the volume of traffic); and for 6 stops/km by 180-240%.

Characteristics of Use — The characteristics of automobile use directly affect fuel consumption. Among these factors are ambient temperature, automobile occupancy, and driver habits.

- *Ambient Temperature and Trip Length*. The rate of fuel consumption increases as the ambient "cold start" temperature decreases. Trip length also has an influence. As length increases, the cold-start condition becomes a smaller portion of the overall trip and consumption decreases. At a temperature of 20° Celsius, as trip length decreases from 40 km to 10 km, the fuel consumption rate increases by 20%. This relationship is especially significant in the Metropolitan Toronto area because the great majority of trip lengths are of less than 10 km.
- *Auto occupancy*. Efficiency can be improved not only by vehicle improvements, but also by increasing the number of persons in the automobile. Compared to vehicle improvements that may achieve a 25% increase in fuel economy, a doubling of auto occupancy increases fuel efficiency by 100%.

Direct Energy Calculations

Based on fleet fuel efficiency, as previously calculated, private automobile/light truck energy consumption and intensity are calculated through the separate analysis of roadway-segment and

intersection consumption. Detailed calculations of direct energy consumption are contained in the Metropolitan Toronto Area Transportation Energy Study [20]. A general introduction to the topic follows:

- *Segment Consumption*. In general, segment fuel consumption is defined as that associated with movement between intersections with traffic control devices. Segments will also have to be introduced to distinguish links with significantly differing levels of congestion, speed, or terrain. Intersection fuel consumption relates to stopping and idling at intersections controlled by traffic control devices (e.g., stop signs and traffic signals) or at pedestrian crosswalks.
- *Intersection Consumption*. The consumption of energy associated with intersections is divided into stopping and idling where traffic control devices (stop signs or traffic signals) are present.

4.2 Indirect Energy Consumption

Indirect energy includes energy used in the

- manufacture and maintenance of vehicles;
- manufacture and construction of infrastructure and supporting facilities;
- operation and maintenance (including periodic rehabilitation) of infrastructure and supporting facilities.

Manufacture and construction energy is a one-time initial investment that must be converted to an annual base by considering service life in years or kilometres of travel.

Highway estimates of indirect energy consumption by trip made consider average annual daily traffic on the segment under analysis. Additional sophistication in this trip estimate could be achieved through consideration of passenger car equivalents for trucks and the definition of equivalents for bus transit.

Indirect Energy Estimates

Many estimates exist of the energy required to manufacture materials and construct elements of a transportation project. These estimates have evolved by two basic procedures. The first is based on economic input/output models and the second on analysis of manufacturing or construction processes.

The economic input/output model makes use of factors developed for energy consumed per dollar value. Based on the dollar value of the material to be analysed, a factor is applied and total energy consumption is estimated. The process approach attempts to measure energy consumption in the actual processes during manufacturing or construction.

Highway Construction Energy — The reconstruction of a four-lane urban arterial is estimated to require 1823 GJ/km. Paving materials are estimated to contribute up to 80% of the construction and materials energy consumed in the construction of a highway. As summarized in Table 7.2, a cement-treated base was shown to be the most heavily energy-intensive contributor to such a project.

Table 7.2

Arterial Road Re-construction Energy*

Activity	Energy consumption GJ	GJ/km
1. Removal of concrete base	540	140
2. Excavation	216	50
3. Remove sidewalks	545	140
4. Remove curb	13	3
5. Granular "A"	364	90
6. Cement treated base	5127	1280
7. Concrete curb	82	20
8. Concrete sidewalks	170	40
9. Asphalt base	127	30
10. Asphalt surface	109	30
Total		1823
Per lane-km		455

SOURCE: Metropolitan Toronto Department of Roads and Traffic

* For 4 lanes, 4 kilometres

The construction, including structures, of a kilometre of Highway 404, a 4-lane expressway, is estimated to have required nearly 49 000 GJ/km as shown in Tables 7.3 to 7.5. In this case, the heaviest energy consumption was clearly for construction of the structures.

Highway Maintenance Energy — In general, four-lane urban arterials require maintenance of the highest energy intensity — approximately 162 GJ/lane-km. Rural two-lane and freeway maintenance require 41.1 and 19.1 GJ/lane-km, respectively, as in Table 7.6. The heaviest energy consumers in the freeway and rural road maintenance program are hot patching, snow-ploughing, and winter salting and sanding. (Note that gasoline and diesel consumption figures were not available.)

Vehicle Manufacturing Energy — Estimated manufacturing energy consumption for automobiles is between 125 000 and 140 000 megajoules. Size, weight, and added options account for the wide range used. Also contributing to the differences are manufacturing and industrial efficiencies.

To develop estimates of vehicular manufacturing energy, the process energy was assumed to equal the materials energy content (i.e., vehicular manufacturing energy — 2 × material energy). This factor produced reasonable results in comparison

to other published figures. It should be noted that industrial processes will vary significantly, accounting for a wide possible range in manufacturing energy.

Comparison of Highway Types

While freeway construction and maintenance, expressed in annual terms, require the greatest investment in energy per km, two-lane roads require the greatest energy intensity when traffic volumes are considered (as indicated in Table 7.7).

The estimate of vehicle energy does not include estimates of periodic automobile maintenance or periodic rehabilitation that may be necessary during the effective service life of the automobile. Regardless of the facility estimates, *vehicle manufacturing contributes about 90 percent of the total indirect energy*. The difference in total indirect energy per vehicle-km between the high (two-lane) and the low (freeway) consumption levels is only about 15 percent.

Table 7.3

Expressway Construction Energy — Highway 404 Roadway (4 lanes. 11.28 km) *

	Unit	Quantity	Energy Consumption (GJ/km)	Distribution (%)
Earth excavation	Litres of fuel			
Scraper	L	86 860	3 340	21.0
Truck and shovel	L	51 925	2 000	12.6
Ditching	L	415	15	—
Mucking	L	720	30	0.2
Trim and clean	L	1 510	60	0.4
Subtotal		141 430	5 445	34.2
Granular C - roadway	t	25 620	985	6.2
Granular - backfill	t	725	30	0.2
Granular A	t	14 610	560	3.5
Asphaltic concrete	t	16 055	620	3.9
Reinforcing steel	t	20	1 170†	7.3
Concrete in culverts	m^3	14 235	500†	3.1
Rigid sewer	m^3	1 325	2 810†	17.7
CSP	t	15	880†	5.5
Subtotal			13 000	81.8
Miscellaneous @ 10%			1 300	8.2
Subtotal			14 300	89.9
30% of sewer pipe, reinforcing steel, concrete			1 608	10.1
Total travelled way			15 900	100.0

SOURCE: Wilbur Smith and Associates, *Metropolitan Toronto Area Transportation Energy Study*, Background Report II. Toronto 1980.

* Note that indirect energy varies by type of facility and location (e.g., rural vs. urban); Hwy. 404 is a rural example.

† Noted items include materials energy, not inclusive of direct (on-site placement) energy consumption.

Table 7.4 A

Expressway Construction Energy — Highway 404 Structures

	Unit	16th Avenue Overpass Quantity	16th Avenue Overpass Total (GJ)	16th Avenue Overpass Distribution (%)	Rouge River Bridge Quantity	Rouge River Bridge Total (GJ)	Rouge River Bridge Distribution (%)	Beaver Creek Bridges Quantity	Beaver Creek Bridges Total (GJ)	Beaver Creek Bridges Distribution (%)
Earth excavation	m^3	285	22	0.1	104	10	0.0	32		0.0
Driving steel ("H") beams	t	319	19 140	53.2						
Reinforcing steel	t	104	6 094	16.9	149	8 731	40.2	56	3 270	42.5
Concrete bridge retaining wall	t	931	2 332	6.5						
Stressing steel	t	67	3 915	10.9						
Driving shoes	t	4	217	0.6						
Steel forms	t	14	791	2.2						
Steel barrier rails	t	1	76	0.2	2	129	0.6		61	0.8
Plywood	t	16	136	0.4	24	210	1.0	11	98	1.3
Boards	t	5	14	0.0	60	171	0.8	27	78	1.0
Concrete in bridge foundation	m^3				1 378	3 511	16.2	2 432	52	0.7
Concrete piles	m^3				179	379	1.7	64	140	1.8
Concrete in deck and barrier walls	m^3							386	1 009	13.2
Steel tube piles	t				102	6 467	29.8	31	2 223	28.5
Driving shoes	t					140	0.6		83	1.1
Subtotal			32 737	90.9		19 748	90.9		7 023	90.9
Miscellaneous @ 10%			3 274	9.1		1 975	9.1		702	9.1
Total			36 011	100.0		21 723	100.0		7 725	100.0

Table 7.4B

Expressway Construction Energy — Highway 404 Structures (continued)

	Unit	Regional Road #49 Underpass Quantity	Regional Road #49 Underpass Total (GJ)	Regional Road #49 Underpass Distribution (%)	Regional Road #25 Underpass Quantity	Regional Road #25 Underpass Total (GJ)	Regional Road #25 Underpass Distribution (%)
Excavation	cy^3	116	11	0.1	521	48	0.2
Reinforcing steel	t	67	3 093	31.5	158	9 282	35.3
Concrete in bridge foundations, piers etc.	m^3	890	2 270	23.1	3 139	7 550	28.7
Transverse stressing system		43	3 082	31.4	99	6 439	24.5
Steel barrier rail	t	1	73	0.7	1	84	0.3
Plywood	t	19	169	1.7	24	210	0.8
Boards	t	83	237	2.9	102	293	1.1
Subtotal			8 935	90.9		23 906	90.9
Miscellaneous @ 10%			894	9.1		2 391	9.1
Total			9 829	100.0		26 297	100.0

SOURCE: Wilbur Smith and Associates, *Metropolitan Toronto Area Transportation Energy Study*, Background Report II. Toronto 1980.

Table 7.5

Expressway Construction Energy — Roadways and Structures*

	GJ/km
Roadways	15 900
Structures†	9 006
Total	24 906
Per lane-km	6 226

* Figures are derived from Tables 7.3, 7.4A, and 7.4B.
† Total energy for all structures: 101 585 GJ.

Table 7.6

Highway Maintenance Energy

	Freeway, four-lane			Rural Road, two-lane			Urban Arterial, two-lane		
Maintenance element	Quantity	GJ	GJ/km	Quantity	GJ	GJ/km	Quantity	GJ	GJ/km
Hot-mix patching	540 t	4 100	30.4	490 t	3 420	38.6	—	—	—
Grass mowing	3 230 L	122	0.9	520 L	18	0.2	—	—	—
Snow plowing	109 080 L	3 800	28.1	14 400 t	2 174	24.6	154 530 L	5 380	7.0
Winter sand	7 200 t	1 815	13.4	5 400 t	1 361	15.4	—	—	—
Winter salt	2 250 t	501	3.7	1 080 t	240	2.7	75 000 t	16 700	21.9
Pavement markings				1 360 L	47	0.5	—	—	—
Granular "A" shoulders				250 t	26	0.3	2 000 t	46	0.3
Equipment							472 680 L	16 470	21.6
Gasoline							1 249 900 L	43 550	57.0
Diesel							818 100 L	31 630	41.4
Scarifying							50 000m^3	6 010	7.9
Concrete							1 000m^3	1 769	2.3
Propane									
Total		10 338	75.6		7 286	82.3		123 775	162.0
Per Lane-km			19.1			41.1			81.0

Source: Wilbur Smith and Associates, *Metropolitan Toronto Area Transportation Energy Study*, Background Report II. Toronto 1980.
Notes: (1) Energy content: gasoline = 34.84 MJ/L; diesel = 38.66 MJ/L
(2) For freeway and rural road items 8, 9, and 10 not available.

Table 7.7

Indirect Energy, Highway and Automobile

1 Facility Type	2 Total Construction and Manufacture[1] (GJ/km)	3 Service Life (yr)	4 Annualized Construction and Manufacture (GJ/km/yr)	5 Annual Operations and Maintenance (GJ/km)	6 Total Facility (4+5) (GJ/km)	7 Annual Auto Passes (000)	8 Facility Energy (6:7) (MJ/v-k)	9 Vehicle Manufacture[2] (MJ/veh)	10 Vehicle Life[3] (km)	11 Vehicle Energy (9:10) (MJ/v-k)	12 Total Indirect Energy Intensity (8+11) (MJ/v-k)
Freeway[4]	116 550[5]	50	2 331	80	2 411	33 000[4]	0.073	130 000	100 000	1.300	1.373
Arterial[6]	96 780[7]	50	1 936	123	2 059	9 125[6]	0.226	130 000	100 000	1.300	1.526
Two-lane[8]	35 013	50	700	123	823	2 920[8]	0.282	130 000	100 000	1.300	1.582

Source: Wilbur Smith and Associates, *Metropolitan Toronto Area Transportation Energy Study*, Background Report II. Toronto 1980.
1 Includes 5 rehabilitations at 10% (of construction energy) each
2 Automobile
3 100 000 km life assumed: *Motor Vehicle Facts and Figures 1979*. MVMA, Detroit.
4 Queen Elizabeth Way/Gardiner Expressway
5 116 550 GJ/km = 6 226 GJ/lane-km × 2.34 × 8 lanes (including frontage); 2.34 = urban/rural correction factor
6 Bloor Street West
7 IBI Group, "Indirect Energy in Transportation," March 1978
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Appendix

The Effects of Highway Characteristics on Automobile Fuel Consumption

Table A.1

Adjustment for Curvature of Road

Constant speed (km/h)	Correction Factor: Degree (radius, m) of curve									
	1 (1746)	2 (873)	3 (582)	4 (437)	5 (349)	6 (291)	7 (250)	8 (218)	9 (194)	10 (175)
16	1.000	1.001	1.002	1.002	1.003	1.004	1.005	1.005	1.006	1.008
32	1.001	1.002	1.003	1.004	1.005	1.006	1.007	1.008	1.010	1.030
48	1.005	1.010	1.016	1.022	1.028	1.034	1.040	1.080	1.140	1.200
64	1.015	1.031	1.048	1.065	1.082	1.120	1.170	1.230	1.340	1.480
80	1.025	1.054	1.090	1.120	1.180	1.250	1.430	1.610	1.820	1.070
97	1.040	1.080	1.132	1.200	1.300	1.400	1.900	—	—	—
113	1.060	1.120	1.182	1.300	—	—	—	—	—	—

Source: "Running Costs of Motor Vehicles As Affected by Road Design and Traffic," U.S. National Cooperative Highway Research Program (NCHRP), Report no. III (1971).

Table A.2

Adjustment for Ascending Grades

Constant speed (km/h)	Ascending grade (%)									
	1	2	3	4	5	6	7	8	9	10
16	1.11	1.21	1.33	1.43	1.56	1.68	1.83	1.99	2.22	2.49
24	1.14	1.30	1.42	1.58	1.72	1.88	2.08	2.28	2.55	2.84
32	1.16	1.40	1.52	1.72	1.88	2.08	2.32	2.56	2.88	3.20
40	1.16	1.38	1.54	1.75	1.93	2.13	2.41	2.69	3.01	3.35
48	1.16	1.36	1.55	1.77	1.98	2.18	2.50	2.82	3.14	3.50
56	1.16	1.36	1.54	1.74	1.94	2.14	2.46	2.76	3.09	3.44
64	1.17	1.35	1.52	1.70	1.89	2.09	2.41	2.70	3.04	3.39
72	1.15	1.35	1.49	1.65	1.84	2.04	2.34	2.60	2.92	3.26
80	1.13	1.35	1.46	1.60	1.79	2.00	2.27	2.50	2.79	3.12
89	1.14	1.33	1.46	1.60	1.78	1.96	2.22	2.44	2.70	3.02
97	1.16	1.31	1.45	1.60	1.76	1.93	2.17	2.38	2.62	2.93
105	1.14	1.28	1.42	1.56	1.71	1.88	2.09	2.30	2.52	2.81
113	1.12	1.25	1.39	1.52	1.66	1.82	2.01	2.21	2.42	2.69

Source: NCHRP III.

Table A.3

Adjustment for Descending Grades

Constant speed (km/h)	Descending grade (%) 1	2	3	4	5	6	7	8	9	10
16	0.83	0.62	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
24	0.82	0.58	0.50	0.49	0.49	0.49	0.49	0.49	0.49	0.49
32	0.80	0.54	0.44	0.42	0.42	0.42	0.42	0.42	0.42	0.42
40	0.78	0.52	0.40	0.37	0.36	0.36	0.36	0.36	0.36	0.36
48	0.75	0.50	0.36	0.32	0.30	0.30	0.30	0.30	0.30	0.30
56	0.76	0.52	0.38	0.31	0.30	0.28	0.28	0.28	0.28	0.28
64	0.76	0.54	0.39	0.30	0.30	0.26	0.26	0.26	0.26	0.26
72	0.78	0.56	0.44	0.35	0.32	0.26	0.26	0.22	0.22	0.22
80	0.79	0.58	0.48	0.40	0.35	0.27	0.25	0.19	0.19	0.19
89	0.81	0.60	0.56	0.46	0.41	0.32	0.28	0.22	0.19	0.16
97	0.83	0.62	0.64	0.52	0.47	0.38	0.31	0.24	0.19	0.16
105	0.85	0.67	0.64	0.55	0.50	0.42	0.36	0.28	0.22	0.16
113	0.87	0.72	0.64	0.58	0.54	0.46	0.40	0.33	0.24	0.19

SOURCE: NCHRP III.

Table A.4

Correction Factors for Rough Surface

Uniform speed of automobiles (km/h)	Correction factors by road surface: High-type concrete or asphalt	Badly broken and patched asphalt	Dry well-packed gravel	Loose sand
16	1.00	1.01	1.09	1.23
32	1.00	1.05	1.13	1.28
48	1.00	1.20	1.26	1.40
64	1.00	1.34	1.56	1.73
80	1.00	1.50	1.70	2.00

SOURCE: NCHRP III.

Table A.5

Excess Litres of Gasoline Consumed Per Slowdown Speed Change Cycle — Automobile

Speed (km/h)	Excess gasoline consumed (litres) by amount of speed reduction before accelerating back to speed (km/h): 16	32	48	64	80	97
32	0.0120	—	—	—	—	—
48	0.0130	0.0234	—	—	—	—
64	0.0140	0.0257	0.0352	—	—	—
80	0.0160	0.0280	0.0401	0.0529	—	—
97	0.0170	0.0310	0.0454	0.0586	0.0718	—
113	0.0190	0.0340	0.0491	0.0631	0.0767	0.0919

SOURCE: NCHRP III.

Table A.6

Excess Litres of Gasoline Consumed Per Stop-Go Speed Change Cycle — Automobile

Speed (km/h)	Excess gasoline consumed (litres) by duration of stopped delay (seconds)						
	0	30	60	90	120	150	180
16	0.0190	0.0250	0.0440	0.0630	0.0820	0.1010	0.1200
32	0.0249	0.0439	0.0629	0.0819	0.1009	0.1199	0.1389
48	0.0366	0.0556	0.0746	0.0936	0.1126	0.1316	0.1506
64	0.0483	0.0673	0.0863	0.1053	0.1243	0.1433	0.1623
80	0.0635	0.0825	0.1015	0.1205	0.1395	0.1505	0.1775
97	0.0786	0.0916	0.1166	0.1356	0.1546	0.1736	0.1926
113	0.0919	0.1109	0.1299	0.1489	0.1679	0.1869	0.2059

SOURCE: NCHRP III.

Table A.7

Correction Factors for Traffic Volume — Six-lane Expressway

One-way Traffic Volume (vph)	Correction factors by attempted speed of automobiles (km/h)			
	72	80	88	97
0 - 2400	(Level of service A = free-flowing traffic)			
2400 - 2800	1.000	1.000	1.010	1.020
2800 - 3200	1.000	1.005	1.015	1.025
3200 - 3600	1.000	1.010	1.020	1.030
3600 - 4000	1.000	1.015	1.030	1.045
4000 - 4400	1.001	1.020	1.040	1.060
4400 - 4800	1.002	1.030	1.050	1.070
4800 - 5200	1.003	1.032	1.060	1.078
5200 - 5600	1.004	1.036	1.070	1.085
5600 - 6000	1.005	1.040	1.080	1.090
6000+	(Level of service E = unstable flow)			

SOURCE: NCHRP III.

Table A.8

Correction Factors for Traffic Volume — Six-lane Major Street Urban Arterial with No Parking

One-way Traffic Volume (vph)	Correction factors by attempted speed of automobiles (km/h)			
	48		64	
	No stops	1 stop/km	No stops	1 stop/km
0-1000	1.000	1.384	1.000	1.466
1000-1200	1.000	1.384	1.000	1.468
1200-1400	1.005	1.386	1.010	1.470
1400-1600	1.005	1.388	1.020	1.472
1600-1800	1.010	1.390	1.020	1.474
1800-2000	1.010	1.392	1.030	1.475
2000-2200	1.010	1.394	1.030	1.477
2200-2400	1.020	1.396	1.040	1.478
2400-2600	1.030	1.398	1.040	1.480
2600-2800	1.040	1.398	1.050	1.481
2800-3000	1.050	1.400	1.060	1.481
3000+	(Level of Service F = unstable flow)			

SOURCE: NCHRP III.

Table A.9

Correction Factors for Traffic Volume — Six-lane CBD Streets With Parking in Both Curb Lanes *

One-way Traffic Volume(vph)	Correction factors by frequency of stops per km † ‡						
	0	1	2	3	4	5	6
0 - 40	1.00	1.29	1.59	1.87	2.19	2.40	2.74
40 - 80	1.00	1.29	1.59	1.87	2.19	2.40	2.74
80 - 120	1.00	1.32	1.62	1.91	2.22	2.50	2.81
120 - 160	1.00	1.33	1.64	1.93	2.27	2.56	2.86
160 - 200	1.01	1.34	1.68	2.00	2.31	2.61	2.92
200 - 240	1.02	1.35	1.73	2.04	2.38	2.68	2.98
240 - 280	—	1.39	1.78	2.12	2.45	2.70	3.07
280 - 320	—	—	1.84	2.19	2.53	2.80	3.16
320 - 360	—	—	1.89	2.29	2.60	2.93	3.21
360 - 400	—	—	—	2.39	2.75	2.98	3.31
400+	(Level of service F = unstable flow)						

Source: NCHRP III.

* Automobiles are assumed to attempt to travel at 40 km / h with traffic signals set approximately 150 m apart. Average stopped delay when stopped is 30 seconds.

† Traffic volume corrections determined for the standard-size U.S. car (65% of vehicle population) represented by a Chevrolet sedan at 2000 kg G.V.W.

‡ When vehicle stops are involved, this table should not be used for grades greater than 1.5%. If grades exceed 1.5%, basic data on fuel consumption owing to stops and traffic conditions should be used to adjust the values.

Ontario

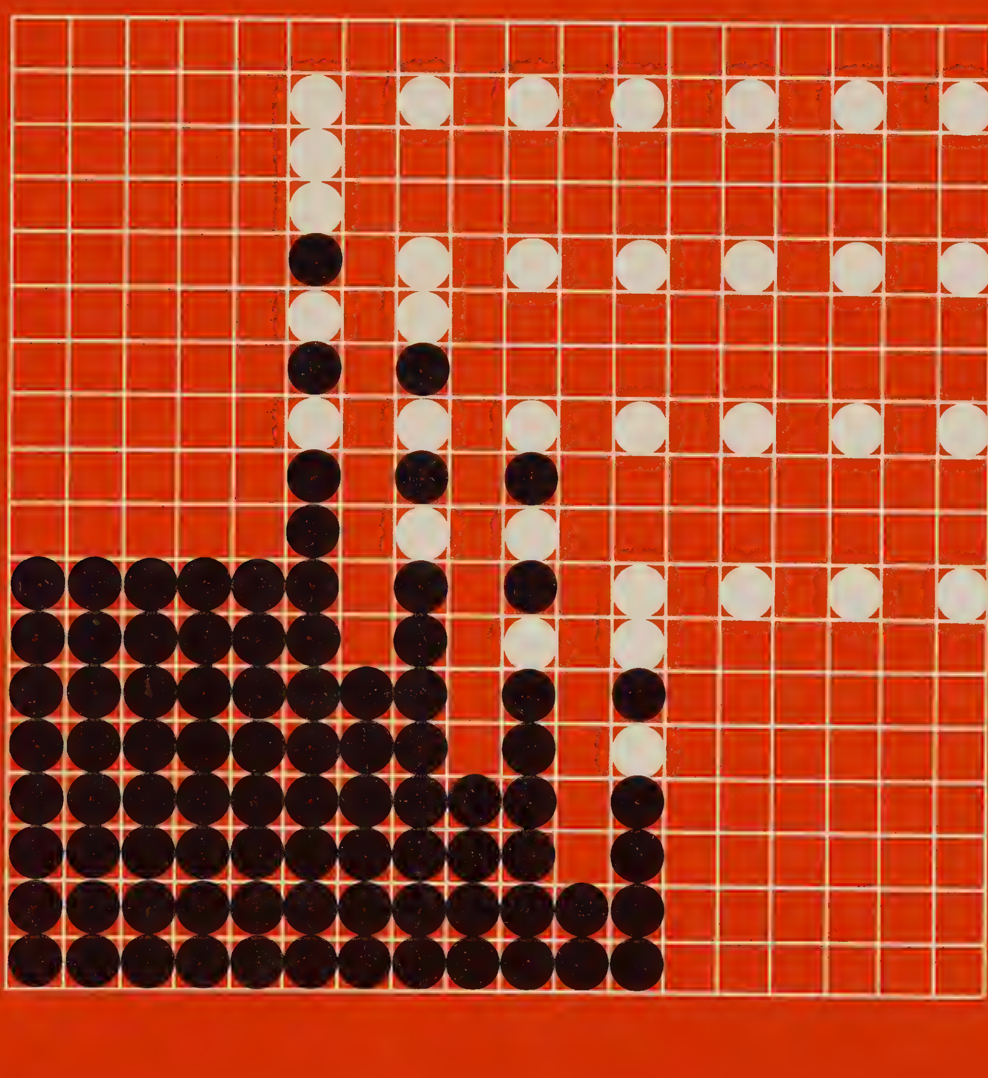
Ministry of Transportation and Communications
Hon. James W. Snow
Minister

Ministry of Energy
Hon. Robert Welch
Minister

Energy Ontario

Transportation Energy Analysis Manual

8: Contingency Planning



The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM
Transportation Energy Analysis Manual

8: Contingency Planning

Published in Consultation with
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by
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Preface

The purpose of the **Transportation Energy Analysis Manual (TEAM)** is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within the municipality. The Manual is organized into ten chapters, which outline the principal technical ways to conserve energy through transportation improvements.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is the crucial public-sector level because these decision-makers deal with the day-to-day activities of thousands of citizens residing within their municipalities. Energy conservation is an on-going, everyday affair, and the municipality is directly involved.

The **Transportation Energy Analysis Manual** will consist of chapters on the subjects listed below. The Manual is being produced chapter by chapter as each is completed. These in turn will be updated as considered necessary.

1. Overview and Summary
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Energy Program Management
10. Energy Analysis Methods

This chapter, **Contingency Planning**, focuses on and highlights the elements basic to planning at a municipal level for potential large-scale petroleum shortages.

Additional information on the Manual or any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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Table of Contents

1 Overview

Fuel shortages, similar to those that have occurred in the United States, could develop in Canada. Should this happen, the federal government would be in charge, and has already established the Energy Supplies Allocation Board (ESAB) to deal with such a situation. During a shortage, the board would have the power to allocate crude oil at the refinery or wholesale level and, in a severe shortfall, to ration gasoline.

Ontario's role would be to assist the federal government by helping to staff regional ESAB offices in Ontario, and by providing administrative and statistical information (such as lists of vehicle registrations) should gasoline rationing be ordered. The Ontario Government would also work to achieve maximum conservation in all its own areas of operations, work with the oil industry to encourage cooperation in coping with the supply problem, and help speed the flow of information between various levels of government, industry, and the public.

Municipalities should also be prepared for such a shortfall — whatever its cause — and the disruption of services such as transportation and road maintenance that would result.

The best way to handle any emergency is to be ready for it. Coping with a shortfall will require discipline. Experience in the U.S. proves that those who implement conservation programs well in advance are better able to react to a serious shortfall, and will do so much faster and more effectively than those who have not previously been involved in conservation programs.

Since a shortfall would affect many different activities, municipalities should study all operations that use fuel — from public transit to garbage collection — and plan accordingly. Transportation, public and private, is the major area of concern because of its dependence on petroleum fuels and the need to maintain mobility.

Setting up a contingency plan in advance is similar to taking out an insurance policy — it is there if you need it. An added benefit of establishing a contingency plan is that the experience and insights gained in developing the plan can lead to more efficient fuel usage in day-to-day operations. It is important to note that contingency planning, like all successful planning, is a process and not an isolated event.

2 Introduction

Canada has never experienced a major gasoline shortage in peace time, and until the 1970s neither had the United States. Both the U.S. and Canada have to rely to a greater or lesser extent on imported petroleum. Since both countries are similar in the way they use gasoline and other petroleum products, we know that what has happened in the U.S. could also happen here. Although there is no imminent danger of Canada experiencing a major petroleum shortage, it is wise to be prepared.

If a fuel shortage were to occur, the primary responsibility for allocating available petroleum would rest with the federal government. That responsibility, the way the federal government might choose to fulfill it, and the supporting role the Ontario Government would be able to play in such a situation are discussed in the following sections.

In a shortage, municipalities would face specific problems. The impact of a fuel shortage on areas of municipal responsibility, such as road maintenance and other public works activities, could be substantial. What is more, municipal governments would be expected to undertake a range of actions — for instance, provide additional public transit to allow an increased number of people to leave their cars at home, help form carpool and vanpool programs, and regulate the way fuel is sold to avoid confusion and panic. The development of a plan of action to cope with such eventualities is advisable. As was shown in Mississauga in the 1979 train derailment, preparedness can mitigate the effects of an emergency situation.

Since each municipality is different, it would be impossible to develop a comprehensive plan that would work for all, although the major topics for consideration are the same. A contingency plan for Metro Toronto, for example, wouldn't work for Timmins or Orillia. It would also be impossible to come up with a series of contingency plans for cities of similar sizes. For example, even though Sarnia and North Bay each have a population of about 50 000 people, their transportation needs, traffic patterns, weather, and transportation systems are different.

However, while each municipality requires its own detailed contingency plan, there are common elements and these are discussed in more detail in this chapter.

3 The Federal Role

3.1 Energy Emergency Programs

The Parliament of Canada passed the Energy Supplies Emergency Act in 1979. It gives the federal cabinet the power to declare an energy emergency and to act to resolve it, although parliament must vote to either confirm or revoke this action as soon as possible.

In an energy emergency, the Energy Supplies Allocation Board (ESAB) would be in charge and would implement three major programs, depending on the severity of the shortfall:

- *crude oil allocation*, which can be in operation within a week of declaring an emergency;
- *wholesale petroleum product allocation*, which can be put in place within sixty days of declaring an emergency;
- *gasoline rationing*, which can go into effect within six months of declaring an emergency.

To supplement these main programs, ESAB can also create and implement allocation and pricing programs for coal, natural gas and, with the agreement of the provinces, electricity. The Board can also override the National Energy Board Act, grant exemptions to the Combines Investigation Act, and relax environmental safeguards.

It is important to remember that the federal government has not said exactly what an energy emergency is. It could be gradual or abrupt, domestic or foreign. Even an oil shortage in a foreign country could become a Canadian ''emergency,'' because Canada is a member of the International Energy Agency and IEA members have agreed to share oil with other member nations during shortages. Also unspecified is the point at which a ''shortage'' would become an ''emergency.''

3.2 Crude Oil Allocations

This program could be in operation within a week of declaring an emergency and would put *all* Canadian crude oil — from both domestic and foreign suppliers — under ESAB control.

While controlling all crude oil distribution inside the country, ESAB would order it shared among Canadian oil refineries to make sure there would be an efficient refining and distribution system, with as little disruption as possible. Refineries could be required to buy and sell oil among themselves to meet ESAB's distribution goals; ESAB has the power to exempt oil companies from the Combines Investigation Act.

3.3 Wholesale Petroleum Product Allocation

This program would be aimed at bulk or wholesale purchasers of gasoline, heating oil, diesel fuel, heavy oil, and aviation fuel, and would take effect only if crude oil allocation was not sufficient. It could start within sixty days of the emergency being declared.

ESAB has placed bulk purchasers into three priority groups: ''Critical'' (A), ''Essential'' (B), and ''Non-essential'' (C) (see Table 8.1). The services and industries within each group would be allowed a percentage of their regular requirements, although even in category A this might not be 100% of the historical demand.

Although the program is a federal responsibility, ESAB could borrow employees from industry and provincial governments to help administer it through regional offices.

3.4 Gasoline Rationing

If allocation programs are insufficient to cope with the demand for reduced volumes of fuel, actual gasoline rationing could start within six months of an energy emergency being declared. ESAB would use the Post Office to issue monthly ration coupons to the owners of all registered vehicles. Separate coupons would be issued for business use.

Although ESAB does not plan to issue ration coupons for out-of-province tourists or visitors, or to drivers who do not own a registered vehicle, there may be a small ''float'' of extra coupons which each regional ESAB office could distribute to individuals with special needs.

People with more coupons than they needed could, of course, sell them. ESAB would monitor the market and control prices.

Table 8.1

Summary of Classification Categories

Controlled petroleum products except those used for space heating/cooling		Controlled petroleum products used for space heating/cooling
	Critical Category (health, welfare, security)	
A	Agriculture and food processing (primary agriculture, food production, and the processing of essential, perishable food products)	C
A	Air flights (remote areas)	C
A	Commercial fishing	C
A	DND operations	C
A	Energy production and distribution	C
A	Fire, police, and ambulance	C
A	Hospitals and health care	A
A	Marine bunkering (northern areas)	C
A	Public transportation	C
	Essential Category (economic stability)	
B	Agriculture and food processing (other agriculture and food and beverage industries not included in category A)	C
B	Air flights (commercial pilot training)	C
B	Car rentals	C
B	Construction industry	C
B	Forest industry	C
B	Freight transportation (road, rail, water)	C
B	Garbage collection	C
B	Manufacturing	C
B	Marine bunkering	C
B	Mining	C
B	Postal service	C
B	Public utilities (telephone, water)	C
B	Retail motor fuel outlets - diesel	C
B	Snow removal, road maintenance (streets and highways)	C
B	Service industries (retail delivery, consumer service, etc.)	C
B	Office buildings, merchandising, and warehouses	C
B	Taxis	C
	Non-Essential Category (maintenance of standard of living)	
C	Government (federal, provincial, and municipal)	C
C	Hotels and motels	B
C	Marinas	C
C	Misc. and unclassified	C
C	Recreational activities	C
C	Residential and apartments	C*
C	Schools	B*
C	Retail motor fuel outlets - gasoline	C

* Subject to review

4 Ontario's Role in the Federal Program

Ontario's role in a national emergency would include assisting the federal government in such ways as:

- helping to staff the regional Energy Supplies Allocation Board offices in Ontario;
- providing ESAB with administrative and statistical information it might need, such as a list of vehicle registrations, should gasoline rationing be ordered.

In addition, of course, the Ontario Government would work to achieve maximum conservation in all its own areas of operation. Existing conservation programs (Ontario Government Fleet Energy Management Program, Employee Energy Savers Program) would be emphasized to ensure the realization of maximum possible savings.

The Government of Ontario would work closely with the oil industry to encourage its cooperation in coping with the supply problem. The provincial government would also act in a communications role to facilitate the flow of information between the various levels of government, the oil industry, and the public.

5 Municipal Role

5.1 Municipal Energy Plans

In the event of a disruption in the normal supply of transportation fuel, for whatever reason, a municipality will have to make some important decisions in three key areas:

- maintaining its own operations;
- coping with an increased demand for public transit;
- interfacing with the public: e.g., service station retail policies, parking policies, traffic management.

One key variable in an emergency is its anticipated duration. Obviously, if the supply disruption were to last for only a short period, say a week or two, it would be relatively easy to deal with. However, if the situation were expected to last for several months, a different group of actions would be needed to alleviate problems. A good contingency plan should be sufficiently flexible to be usable in either situation by having stages of implementation.

Another scenario is a short-term, highly localized disruption caused by events such as a refinery breakdown or severe weather conditions. Such a situation may not trigger the federal programs because of its localized nature, and a municipality with a well-thought-out contingency plan would obviously be in a better position to cope with its problems than one that was not well prepared.

5.2 Municipal Operations

A key variable during a shortfall situation is the amount of gasoline under municipal control. A municipality that does not have bulk storage facilities should consider the fact that while some of its operations (such as garbage collection, snow removal, and road maintenance) get a high priority under federal fuel allocation programs, automobile service stations do not. If fleet vehicles customarily get gasoline from such outlets, there may be problems. The priorities various users would get were listed in Table 8.1. A municipality should prepare a priority list for all of its activities. Fuel allocation would be based on these priorities.

It is also useful to determine in advance what machinery or vehicles, if any, could be operated on other fuels such as propane, compressed natural gas, or electricity, and to make the necessary conversions. This precaution could reduce the municipality's sensitivity to oil supply problems.

5.3 Public Transit

Dealing with the demand for increased public transit, most of it in the peak periods, will also require careful planning. The experience during moderate shortfalls in the United States was that transit ridership increased roughly 5% during the shortage, with this increase being concentrated on a limited number of routes and in the peak periods. It is important to remember that although transit systems have a high priority under fuel allocation programs, there is no guarantee that they will get all the fuel they want.

Many transit innovations can be implemented prior to any emergency being declared, simply on the basis of improved transit efficiency and effectiveness, and for energy conservation reasons. These tools, once implemented, can be used very effectively to respond to an emergency situation. Chapter 3 of this Manual discusses transit system actions that relate to fuel conservation.

Examples of these tools are computerized passenger information systems like the ones in Mississauga and Ottawa, and transit route design and maintenance programming software that is now available. Of course, these systems must be in place and the transit personnel familiar with their utilization for them to be of any use in an emergency.

One of the key advantages of the computerized transit information system in a shortfall situation is its capability of conveying a great deal of information on schedules, service disruptions, route changes, and so forth, very quickly. Potential riders simply phone a central computer and receive up-to-date information. In its most sophisticated form, the system includes automatic vehicle monitoring so that riders get real-time information and the transit operator can call up an instantaneous picture of the service situation at any time.

Computer software is also available to set up preventive maintenance programs for buses, thus reducing down-time and increasing the efficiency of vehicle utilization — a concern at any time, but especially during a fuel shortfall. Software also

exists to aid in route design and scheduling. If it becomes necessary to modify service, the availability of such software could enable a faster response than is possible manually.

In addition to conservation measures, much can be done by the transit system in advance. For example, old buses can be stockpiled and used on low-volume routes or charters. An arrangement might be made with local school bus operators, churches, and taxi companies to use some of their vehicles if necessary. Some advance planning could be done with respect to which routes would be most likely to need more vehicles and which could tolerate a reduced level of service.

5.4 Other Transportation Programs

As part of the contingency plan, a municipality should study areas in which it might be able to alleviate the potential mobility problems of its residents. For example, municipalities should consider the possibilities and difficulties associated with ridesharing programs, shared-ride taxis, and parking policies to support transit use and ridesharing. There may be opportunities to increase traffic mobility through fine tuning the traffic-signal timing patterns. Travel demand can be modified through variable work hours.

All of these areas are discussed in other chapters of this Manual. Conservation can be one of the best ways of avoiding energy shortfalls. As noted earlier, municipalities already involved in energy conservation are able to adapt to major shortfalls more readily than those which are not.

6 Designing a Plan

6.1 Start with Conservation Programs

The basis of any contingency plan is conservation. Experience in the United States has shown that when a supply shortfall occurs, the municipalities that experience the least disruption are those which already have effective conservation programs in place. This is because it is much easier to tighten existing measures than to suddenly impose new ones, and because there is a base of experience for determining where the biggest gains are to be made for a particular municipality. Another advantage is that the discipline of implementing a conservation program usually means that the municipality has established a good data base and is better able to respond quickly to emergencies, plan effective strategies, and document its requests to the senior levels of government for fuel allotments.

6.2 Current Usage Information

A contingency plan should address every area in which fuel is used in the municipality. While many factors will not be under municipal control, it is vital to establish the linkages. To create such a plan, municipal officials should consider which services can be reduced, eliminated, or integrated to save fuel. Furthermore, a municipality should be able to adapt its plan to the amount of fuel available and the length of time the emergency can be expected to last. In other words, flexibility is a key component of any such plan.

Before any plan can be made, it is important to know exactly how much fuel is used in every municipal operation, including each vehicle and machine. To do this, it is vital that comprehensive records be kept. Should allocation or rationing come, these records will help ensure that the municipality receives the fuel to which it is entitled. Keeping good records also makes it easier to develop ways of conserving fuel, and can help with preventive maintenance programs. Chapter 6 of this Manual, *Municipal Fleet Management*, deals with this item as well as other fleet-related measures.

6.3 Identification of Key Personnel

One of the fundamentals in implementing a contingency plan will be the prior identification of key players, along with their participation in the design and periodic updating of the plan. Such people as the transit manager, police chief, and representatives of other emergency services should be included, together with the mayor, city manager, commissioners, and senior department heads. Union representation is desirable since some actions can affect contracts.

In a fuel shortage situation, one of the most important tasks is to maintain mobility, especially for the work force. Transit and ridesharing are key programs in achieving this objective. Therefore, in addition to establishing the steps for maximizing transit services, carpool and vanpool programs at major employment centres will be very important. Full ridesharing potential can be achieved only after several months of work. Therefore, advance preparation in the form of identification of major employers, naming of a coordinator in each company, printing of forms and instructional material, and distribution of materials are all desirable in order to save time and be ready if an emergency situation arises.

6.4 Key Steps in Plan Development

While it is impossible to design a master contingency plan that would work for every Ontario municipality, it is possible to list key factors which every contingency plan should address. In March 1980, the U.S. Department of Transportation (DOT) published *Transportation Energy Contingency Strategies, Part 1, The Planning Process*. This document is the result of U.S. experience during the 1973-74 and 1979 fuel shortages, and recommends a twelve-step process which can be tailored to almost any municipality's needs. The steps are:

- Assess the national, state, and local impacts of the 1973-74 fuel shortages on automobiles

and the demand for public transportation and ridesharing services using data available from current sources. (This step is of limited direct utility in Ontario, but does constitute useful background information. Many summaries of the U.S. experience exist, some of the best having been done by the New York State DOT).

- Analyze current fuel-supply conditions and develop procedures to monitor changes in supply and consumption.
- Analyze existing transit, paratransit, and ridesharing services, vehicles, and ridership to determine available capacity and fuel requirements, and to plan better ways of using existing services.
- Analyze the likely demand for multi-passenger transportation services (both magnitude and location) that would be stimulated by future fuel shortages of varying severity.
- Analyze and select actions to increase the capacity of existing services.
- Analyze and plan new services that can be instituted in response to a fuel shortage.
- Develop a fuel-management plan that includes conservation measures and steps to increase fuel supplies.
- Coordinate overall municipal contingency planning with other plans prepared by, for example, transit and police agencies. In particular, this coordination must define the boundaries of each agency's actions.
- Coordinate the plan with other ongoing local programs, especially those which enhance energy conservation.
- Integrate the plan with the actions that senior levels of government may take in response to fuel shortages.
- Prepare an implementation strategy for the plan which details assignments of responsibilities and the timing of actions. (Note: Assignment of responsibilities is only part of the task: people should also be trained in the performance of their duties.)
- Periodically update the plan.

6.5 Synopsis of Transit, Paratransit, and Ridesharing Energy Contingency Planning Actions

The U.S. DOT also produced *Part 2, Synopsis of Actions* in March 1980. While based on U.S. experience and institutional structures, and thus not completely transferrable to the Canadian context, the following list of possible actions provides a useful framework for the contingency planning process.

Actor: The Transit Operator

The operator should have four primary objectives in planning an energy contingency strategy:

- *Public Information* — to provide adequate information to current and new riders regarding available vehicle capacity, operating conditions, routes, and schedules.
- *Fuel Efficiency* — to economize in the use of fuel.
- *Fuel Availability* — to obtain sufficient fuel to sustain and expand levels of service.
- *Service Expansion* — to accommodate increased demand.

The four objectives are tied together, since service expansion to accommodate additional ridership generally entails increased fuel requirements. At the same time, actions taken to conserve fuel may involve service changes and communicating these changes to the public may tax the public information capability of the transit operator.

In addition to pursuing these primary objectives, the operator must assist the community at large with a transition towards greater use of public transportation; establish communications with major employers who may now need new service; coordinate activities with other transportation service providers; and expand information programs on all public transportation services in the region. In some cases, transit authorities might assume a lead role in such coordination activities. The actions described below focus on the objectives and responsibilities of the transit provider concerning public information, fuel supplies, and service expansion.

1. Actions to Improve Public Information

A public information program should be a basic component of every transit system. During an energy shortage this basic program can be changed or expanded as the need arises. Accommodating demand during an emergency requires that existing riders be informed about changes in service that will affect them. New and potential riders must be informed about the services available to them and about methods of using the system. For these purposes, a comprehensive multi-media public information program should be prepared in advance and implemented at the onset of an emergency. This kind of program should provide information on such things as:

- types of services
- location of routes and stops
- schedules and schedule changes
- fares
- location of information centres
- underutilized services (time of day / route)
- how to use the system

- auxiliary public transportation options (e.g., dial-a-ride services)
- carpooling and ridesharing alternatives

Establish an Expanded Public Information Program — In anticipation of rising prices and supply uncertainty, public information activity should be significantly upgraded and increased to inform riders of services (e.g., expanded distribution of timetables, route maps, fare structures, etc.) and the concept of using transit should be promoted. The public information system is the most likely service to break down during severe shortages. Unanswered telephones will exasperate the public. Prior planning is needed to ensure that the system can respond to the public's request for telephone information and that accurate and useful information will be provided concerning actual operating conditions. It might be more effective if a multi-service emergency information centre were established to provide information on all transportation modes.

Establish Multi-Modal Telephone "Hot-Line" — An important medium of public information during an emergency can be an adequately staffed regional public transportation telephone information service. Such a service should provide coordinated and integrated information on all regional public transportation systems as well as paratransit and ridesharing. The service may or may not be operated by the transit operator, but the operator will have an obvious stake in the effectiveness of such a service. Planning for the "hot-line" service should be accomplished prior to any major shortage. This work may include preparation of instruction packets for phone operators and arrangements with the telephone company for special phone numbers and priority treatment during an emergency. The emergency phone information system should be implemented and expanded as necessary.

Establish Emergency Media Program — An emergency media program, using the print media, radio, and television, should be prepared in advance and implemented when necessary. It should also involve preparation and dissemination of pamphlets, posters, etc.

The aims of this media program would include:

- to explain the energy situation;
- to provide information on transit use (schedules and route information);
- to explain how to use the transit system under crowded conditions;
- to encourage travel in off-peak periods;
- to encourage the use of carpools, vanpools, etc.;
- to promote public transit use (if capacity is available).

2. Actions to Improve Fuel Efficiency

The actions discussed in this category are oriented primarily towards increasing the fuel efficiency of the transit system. That is to say, these actions aim at increasing the passenger-miles of services provided per litre of fuel consumed. Such actions could be used either to expand system capacity with constant fuel supplies or to maintain overall system capacity with shrinking fuel supplies. Also, because of the dramatic increase in diesel fuel prices, it may be desirable to change operating practices even in the absence of a fuel shortage.

Reduce Vehicle Stops — Vehicle fuel efficiency is improved by reducing the frequency of stops and starts for individual vehicles. Such a reduction can be achieved in several ways, some of which do not require elimination of any stops on the route. For example:

- Consider stop-skipping, express, and semi-express service.
- Eliminate selected stops under severe energy shortages.

Reduce Deadheading — While unnecessary deadheading should be avoided even in normal times, the exigencies of a fuel emergency could justify certain measures to reduce deadheading that would not make sense under conventional circumstances. In general, deadheading may be reduced by relocating vehicle storage and maintenance sites, by providing layover sites in the area, and by modifying existing routes and schedules. (It should be noted that bus routes which normally are not heavily patronized during off-peak hours may experience substantial increases in demand during the daytime hours, thus increasing the number of buses in service all day. These changes may affect the need for downtown layover areas.)

Reduce Vehicle Idling and Delay — A variety of measures can reduce the amount of fuel wasted in idling and delaying of vehicles. These measures include improved driver and supervisor training, reduced dwell time at stops, reduced layover time, on-street parking restrictions, reserved lanes, and signal priorities. Such actions require considerable lead time and extensive coordination with other organizations before they can be implemented.

Transit Vehicle Hardware Modification — Actions in this category aim at improving transit vehicle fuel efficiency through augmented engine maintenance procedures, the training of mechanics in energy-conservation procedures, and conversion to alternative fuels (e.g., propane). Such measures may be justified simply by high fuel prices, apart from a supply shortage.

Cut Back Service on Least Efficient Operations — Actions in this category involve the reduction or elimination of service on certain routes or route segments (or during time periods that are

characterized by low ridership). Service reductions are generally a last-resort emergency action. It is essential that an effective monitoring program be developed to identify which routes require less, and which more, service. Where possible, buses should be relocated from minor to major routes to serve critical trips (i.e., work trips).

3. Actions to Improve Fuel Supply Availability

Building or expanding fuel storage is a means both of ensuring fuel availability during a supply interruption and also of reducing average fuel costs during an emergency in which prices rise rapidly. Additional fuel storage can be obtained by leasing, buying, or building a storage facility. The size, cost, and locational proximity of the facility are important considerations. In addition, fuel supplies should be carefully monitored. Low fuel supplies and the possibility of further supply cut-backs will trigger the implementation of other contingency actions.

4. Actions to Expand System Capacity or Availability

Actions disussed in this category are oriented primarily to an emergency expansion of transit capacity. This increased capacity will be necessary during a fuel emergency because of increased peak demand for transit brought on by the inability of motorists to buy gasoline. A severe fuel-supply crisis could cause an enormous percentage increase in transit demand.

Expansion of transit service may involve an expanded service area, new service to specific sites not previously served, and increased frequency on existing routes. This service expansion should be undertaken only in areas of high demand so that the new service will be productive and fuel-efficient.

Increase the Number of Vehicles Available — The number of vehicles available for operation at a given time is a basic determinant of overall transit capacity. The size of a transit fleet can be increased in a variety of ways depending on the severity of the fuel shortage and the availability of diesel fuel for operating the buses.

- Old vehicles can be stockpiled and stored in operating condition instead of being sold when they are replaced by newly purchased ones. This approach may involve some rehabilitation of vehicles.
- Some maintenance operations which are not essential or which can be deferred without risk to public safety or fuel efficiency (e.g., cosmetic maintenance) can reduce the percentage of the fleet that is down on a given day.
- The maintenance effort can be increased through more efficient and/or more resource-intensive maintenance procedures (e.g., expanded maintenance crews, night shifts, larger parts inventories, contracted maintenance arrangements), thereby reducing vehicle "downtime".
- Additional new or used buses can be purchased or leased.
- The transit operator's vehicle fleet can be augmented by the use of supplemental vehicles such as school, church, or charter buses, through special agreements negotiated in advance of the emergency. Since additional vehicles are useless without additional people to drive and maintain them, plans must be developed for personnel augmentation as well. Possible actions in that regard include:
  - Developing and maintaining a list of retired drivers and mechanics willing to work part or full time during an emergency;
  - Exploring the feasibility of temporarily contracting with other agencies or companies for additional driver and maintenance personnel during an emergency (e.g., private mechanics, private bus and school bus companies, etc.);
  - Obtaining modifications in collective bargaining agreements allowing for the temporary use of full- or part-time non-union workers during an emergency.

Different types and levels of actions will be appropriate to increase the number of vehicles available for various different stages or types of emergencies. Such increases, of course, depend on whether there is enough fuel to run the buses.

Increase Vehicle Capacity and Utilization — This action includes measures to increase the number of passenger trips served by a given number of vehicles, physical alteration of vehicles (e.g., removing or rearranging seats to increase standing room), as well as measures to improve vehicle utilization (use of HOV lanes, priority signallization, or increased use of express or skip-stop techniques). Actions that increase vehicle utilization have also been mentioned in the earlier section on "Actions to Improve Fuel Efficiency."

Establish Emergency Park-and-Ride Facilities — Transit service can be complemented, particularly in low-density areas, by the establishment of emergency park-and-ride lots along transit routes. It will be necessary to identify the lots and make arrangements for their use, as well as prepare the necessary public information and signing materials.

During a shortfall — depending on the effects of the shortage — it may be appropriate to expand the number and size of park-and-ride lots. Steps might also be taken to make the park-and-ride system permanent.

Support Efforts to Establish Alternative-Work-Hour-Programs — Transit capacity during an emergency will be most strained during

peak hours, when demand may far outstrip capacity. Major employers in large activity centres should be encouraged to implement staggered work hours and/or flexible work hours for employees. These programs will help to spread the demand peak and will maximize the use of available vehicles. Transit operators should work with major employers and other local officials in establishing such programs.

Actor: Providers and Regulators of Auxiliary Mass Transportation Services

Examples of the types of organizations and agencies within this category are:

- private bus companies (charter, tour, and scheduled bus lines),
- school bus operators,
- taxi-cab and limousine companies,
- rental vehicle agencies,
- social-service agencies,
- public-service commissions,
- departments of education,
- local and regional-level governments.

Actors such as these are responsible for a large share of the public transportation of passengers. Consequently, they should play an important role in responding to and planning for transportation energy emergencies.

Emergency actions by these parties should have two objectives: first, maintaining the essential services for which they are responsible; and second, expanding, improving, and diversifying those services rapidly in coordination with mass transit and private ridesharing actions to provide the most effective overall transportation system possible in a fuel-short environment.

The emergency actions discussed below are grouped into two closely related categories: those oriented towards removal of regulatory barriers, and those oriented towards service expansion, improvement, and diversification. As noted, the list of actions discussed here is illustrative only. It is not to be inferred that all of these actions should necessarily be taken, or that there are not other actions which might be useful.

1. Actions Aimed at Removing Legal and Institutional Barriers to Expanded or Improved Services

Public passenger transportation operations conducted by private and non-transit carriers are governed by a multitude of service, equipment, safety, insurance, and economic regulations, administered principally by provincial and local levels of government. It is very important for responsible authorities to review these regulations in the light of the current energy and economic environment. Many substantive and procedural rules may merit streamlining, updating, or total elimination. Other rules should be changed or suspended temporarily upon declaration of an emergency by a responsible authority.

In reviewing the effect that a fuel shortage may have on public transportation services, responsible authorities should keep four points in mind:

1. There will be an overwhelming public need for new and expanded public transportation services of many types, and that need may arise very suddenly.
2. It will be very important for public transportation services to be provided in a fuel-efficient and economic manner.
3. There will be a need for both creative and flexible responses to the crisis on the part of transportation service providers.
4. There will be a need for inter-modal coordination, cooperation and, in some cases, even substitution.

The items discussed below reflect these general considerations.

Remove Ridesharing Restrictions on Taxicabs — Many jurisdictions which regulate taxicabs have fare and service restrictions that prevent or discourage cabs from offering shared-ride service (i.e., combining trips of separate parties travelling in the same general direction). With appropriate rules regarding fare structure and service choice, such shared-ride services could allow passengers to enjoy less expensive service and allow cab operators to increase their income, while at the same time conserving fuel and preserving the right of those who wish to pay higher fares to obtain an exclusive ride. Shared-ride rules should provide for reasonable equity in the division of ride costs among sharing parties and should offer a monetary incentive to both the taxi operator and the potential passenger to select a shared-ride service.

Remove Regulations Restricting Use of School Buses for Other Transportation — In many jurisdictions, laws or regulations prohibit the use of school buses for other than school and school-related purposes. Yet school buses represent a considerable standing capability for rapidly increasing public transit capacity, assuming of course that ways can be found to accommodate their normal patrons, the schoolchildren. During the summer, or with changes in school hours, school buses could be used during peak travel periods. Otherwise, they could be used in the evening peak and the morning and noon off-peak periods. They could be operated under contract to mass transit operators or to employers, or on their own, according to a regional contingency plan that coordinates their operation with that of other modes and carriers.

Remove Restrictions Preventing Jitneys — Most jurisdictions have laws or regulations preventing the operation of taxi-cabs or other vehicle (e.g., station wagons, vans) along fixed or semi-fixed routes. These laws generally originated in the early days of automobile mass production, when early transit providers feared competition from the increasing number of jitneys. While there may be some circumstances, even during a fuel emergency, in which this shared-ride mode would be counter-productive, there will be numerous other instances where jitneys can play a useful role. They may, for example, provide feeder service to transit lines or shuttle service to or from transit termini. They may also be useful supplements along transit routes that are overcrowded.

Planning should be done to ascertain where and what type of jitneys would be beneficial, both for long-term and ongoing conservation and for fuel-supply emergencies of varying degrees. An effort should be made to obtain a selective or complete removal of jitney restrictions where appropriate. Planning for the public-safety regulation of jitney providers (both drivers and vehicles) should be carried out.

Remove Barriers to Market Entry for Cabs, Private Bus Services, Jitneys — One of the most sensitive issues in attempting to allow private and auxiliary transit providers to respond to the need for an expanded auxiliary-transit capacity is the degree to which barriers to market entry should be relaxed. In many cities the number of taxi-cabs is limited by a ''medallion'' system. Most localities provide some degree of market protection to existing private bus companies on certain routes.

In other cases, public transit authorities have exclusive rights to provide public transportation service and have the power to keep other providers out (there may also be pressure from labour to keep other providers out). Historically, jitney service has been prohibited in order to protect transit and cab markets. The energy situation is likely to require a modification, or at least temporary relaxation, of these prohibitions to market entry. Because the providers who are protected by these prohibitions can be expected to defend their economic interest, this issue is likely to be complex. A successful effort will require careful planning and, possibly, a packaging of modifications (including items of importance to existing providers, such as priority access to fuel for all providers or emergency fare relief to cover increased fuel costs.)

2. Other Actions Aimed at Service Maintenance or Expansion

The removal of regulatory barriers discussed above will often be a necessary action to maintain and expand the transportation services that are provided during a fuel emergency by private and auxiliary carriers. In addition, at least two other types of actions will generally be necessary: (1) securing fuel supplies and (2) effective planning and implementation of new services. The actors who are in various ways responsible for the auxiliary transit services described in this section will have to undertake these actions during and prior to fuel-supply emergencies.

Building or expanding fuel storage is a means of both ensuring fuel availability during a supply interruption and of reducing average fuel costs during an emergency in which prices rise rapidly. Additional fuel storage can be obtained by leasing, buying, or building a storage facility. The size, cost, and locational proximity of the facility are important considerations. If empty storage capacity is available at a time when a supply interruption appears imminent, bulk purchase of fuel on the open market may be warranted to build up fuel reserves. Further, if fuel prices are expected to rise, a financial investment in storage capacity could be self-liquidating in a relatively short period of time.

Plan and Implement New Transportation Services — Private and auxiliary transit carriers can provide a variety of useful transportation services in a crisis. Their services could assume various forms — express, subscription, street hail, demand-responsive, and shuttle services — and they could be used in a variety of ways — neighbourhood collector/feeder, express to activity centres, extra peak-hour capacity parallel to transit, relatively inexpensive off-peak service, and so on. Realization of this potential will require considerable advance and ongoing planning by carriers, regulators, interested parties, and responsible political and administrative officials. The will to implement such services must be established and a realistic financial plan based upon fares, public financing, or a combination of the two, must be developed. Issues such as adequate incentive to private providers, fare levels consistent with consumer protection, and availability of funds must be considered and resolved.

Detailed contingency planning must be attempted. All important parties must be involved and, if possible, agreements among these parties should be obtained at this point. For example, public transit operators, labour unions, regulatory authorities, and potential funding organizations must all work together if useful services are to be implemented. In addition, major employers, shopping centres, and recreational areas will be relevant actors in an energy-short environment. Working relationships must be maintained even if plans and agreements cannot be fully completed during this phase.

The Use of New Organizations to Arrange Transportation Brokerage Services — Perhaps the most significant reason to proceed with a

brokerage concept relates to human service transportation needs. Elderly and handicapped people will experience a disproportionate disruption of their mobility during energy shortages. As public transportation options become overcrowded, the availability of specialized door-to-door services (e.g., taxis) and the use of crowded mass transportation services will diminish for the elderly and handicapped. The organization of a brokerage-type operation that includes the development of contractual relationships with private providers in advance of a shortage could be an important method of responding to the particular needs of the elderly and handicapped.

Actor: Ridesharing Service Coordinators and Promoters

The actors referred to in this section are those public and private agencies or organizations that have official responsibility for coordinating and/or promoting ridesharing (i.e., carpools and vanpools) for work-related and other travel. Such actors will typically include one or more of the following:

- provincial ministries
- public corporations and third-party providers
- local governments
- employers or other private providers
- transit operators

In addition, federal agencies will often be important participants.

The role of these actors in a fuel emergency is a crucial one, for ridesharing offers the greatest potential for short-range fuel-demand reduction. While mass transit may be more fuel efficient than ridesharing when load factors are reasonably high, the relatively small proportion of total trips serviced by mass transit, together with the cost of transit service and its physically limited ability to expand capacity quickly in response to sudden surges in demand, make increased reliance on ridesharing a necessity in a fuel crisis.

The actions described in this section are grouped into two areas: those that focus on employers and those that focus directly on the individual commuter. Experience has shown that effective promotion and facilitation of ridesharing requires both types of actions.

1. Actions Oriented Towards Employers

Since ridesharing requires clusters of trip origins and destinations, and since such clusters occur at the work site for the work trip, the employer is a logical focus for ridesharing promotion. Furthermore, recent experience indicates that efforts to promote increased ridesharing are most effective when they are focused on the employer (because of the latter's particular ability to promote the mode if he or she chooses to do so).

Distribute and Promote Information and Instruction Kit to Employers — Information, instructions, and other tools that are useful in setting up ridesharing programs within companies and work sites should be developed, disseminated, and promoted among all large employers within a region or jurisdiction. The package could include manual ride-matching techniques and instructions for obtaining computer-aided matching assistance from local or provincial agencies, as well as a list of local employers (and contacts) with successful ridesharing programs and suggestions on ways to promote ridesharing within a company or work site.

The package should be developed and prepared in advance of the crisis. Whether and in what way the package should be distributed at this phase is a matter to consider. If a crisis is imminent, it makes sense to distribute such a package immediately. In normal times, however, employers will tend to pay much less attention to this kind of promotional effort than they would after a crisis occurs. Nevertheless, ridesharing makes sense as an ongoing conservation measure, not necessarily dependent on emergencies. To help develop and refine the package, consideration might be given to starting a pilot program that focuses on a few interested employers.

Major employers who have successful company ridesharing programs in the area could be identified and recruited to help promote ridesharing among other companies. Individuals responsible for developing and running ridesharing programs in the ''lead'' companies, together with appropriate government officials, could provide assistance to other companies interested in developing programs of their own. Lead employers should be identified and attempts should be made to recruit them to help other employers get started in ridesharing. The effort should be organized for immediate implementation where appropriate as a long-term conservation action. Working relationships should be established and groundwork should be laid for implementation of the effort immediately after a crisis has occurred.

Mandate Employer-Based Ridesharing Programs — A more severe type of action focusing on employers would involve enactment — by federal or other levels of government — of mandatory energy-conservation laws requiring all large employers to develop and implement programs to encourage and facilitate employee ridesharing. Such laws could take different approaches. One would require employers to take certain specific actions, such as reducing the number of available employee on-site parking spaces, providing employee ride-matching services, and/or instituting company-sponsored vanpools. Another, more

flexible approach would require employers to choose and implement a certain minimum number of actions from a list of alternative programs. A third approach would establish a mandatory "commuter efficiency standard," under which employers would have to take steps to ensure that a certain percentage of all employee commuter travel is by energy-efficient modes (e.g., transit, vanpool, carpool). Using this approach the employer would have complete freedom to choose a method for achieving the standard. Standards might vary according to population or employment density or other criteria.

Mandatory programs such as these may be viewed as extreme measures, suitable for severe situations only. Nevertheless, it may be appropriate to have such laws available on a stand-by basis, both to spur interest and concern among large employers and to be as well prepared as possible for a crisis. From another perspective, a carefully designed program could be cost beneficial and might not require excessive hardship on anyone's part. Indeed, certain kinds of mandatory programs may be most effective as ongoing conservation measures.

Mandatory programs are complex because they involve difficult legal, political, equity, and administrative issues. They should be designed carefully, with input from those who will administer and enforce them as well as from the employers who will be affected by them. The design process will take time — a strong argument for advance design and planning work before a crisis occurs. Furthermore, if they are well designed, mandatory programs might also make sense as long-term conservation programs. In many instances, however, political realities will prevent their implementation apart from a crisis.

Mandatory programs are not appropriate for implementation during a short-term crisis unless they make sense as long-term conservation measures. However, the atmosphere created by such a crisis may spur development of these programs (for stand-by status) and may encourage a more positive and participatory approach by employers and program administrators.

2. Actions Oriented Directly Towards Individual Commuters

While employer-based actions will be particularly effective where employers are committed to the concept, these actions nevertheless are indirect in their approach, since the ultimate target is the individual commuter. It is therefore appropriate and necessary for the actors discussed in this section to consider also actions that are directly oriented towards the individual commuter. Such actions attempt to educate commuters about ridesharing and also facilitate ridesharing (in some cases by making single-occupant vehicle travel more onerous).

Augment Capacity of Regional Commuter Matching Systems — Computerized matching programs offer commuters assistance in finding ridesharing partners. During a fuel emergency, such programs will probably be taxed beyond their capacity because of the demand for matching services. Areas that have such programs, therefore, should develop contingency plans to deal with rapidly increasing demand. Areas without such programs should consider instituting them during or before a fuel emergency. Detailed contingency planning should be carried out, including the identification of reserve personnel, facilities, and funds.

Establish System of Park-and-Ride Lots for Ridesharing and Paratransit — In coordination with the establishment of park-and-ride lots for mass transit, a system of park-and-ride lots could be established during an emergency for ridesharing and other paratransit-type operations. Lots would facilitate the formation of carpools and vanpools as well as the operation of third-party and multi-company vanpools, shared-ride taxi services, and subscription modes. Detailed contingency planning should occur, including agreements with property owners, coordination with mass transit, and some preparation of publicity and informational materials.

Establish Priority Fuel Availability for High-Occupancy Vehicles (HOV) — Various methods of handling priority fuel availability should be explored and considered (e.g., reserved pump islands or special hours at service stations). If the program selected requires registration of bona fide vanpools, it may be useful (both as a contingency measure and as a vanpool promotional device) to begin registering vans before the onset of the crisis. Special cards or stickers to identify the vans might also be issued. Such registration would have to be regularly updated.

Use HOV Exclusive-Use Lanes and Other Physical Impediments and Incentives — Physically separating lanes and roadways and permitting their use only by high-occupancy vehicles during peak hours can significantly encourage the use of ridesharing and transit. Such physical separation improves the service quality of the high-occupancy modes. However, taking existing roadway capacity for exclusive HOV use (as opposed to building additional new exclusive capacity) is very unpopular and therefore politically difficult to achieve. There may be serious safety problems in some cases as well, and the number of roads that can be altered may also be severely limited by cost or capacity considerations.

Exclusive HOV roadways can be effective only when the alternative general roadways are congested (or will be made congested by the HOV lanes). Also, the most politically feasible way to provide exclusive HOV roadways — by addition of new capacity — is a major capital-investment ac-

tion not appropriate as an emergency contingency response. For these reasons, HOV lanes may be most effective as long-term conservation actions, not as emergency contingency actions. To the degree that the HOV lanes do make sense as emergency actions (e.g., to increase transit capacity and fuel efficiency), they require considerable advance planning, coordination between agencies, and other preparations, all of which should start before the onset of a crisis.

HOV lanes will probably only be used as an emergency-response action during a moderate-shortfall situation. A greater crisis would likely eliminate much of the congestion that gives HOV lanes their reasons for being. A shorter crisis would not warrant major physical changes.

Expand Government-Operated Third-Party Vanpool Program — Provincial or local government agencies could further encourage the operation (directly or by contract) of third-party vanpool programs. In third-party systems, the van is owned by an organization or agency independent of the employer or employee; the owner takes care of administrative functions including insurance and possibly ride-matching. Employees (who may be from one or more companies at a common work site) operate the van, with the passengers paying a fare which covers all operating costs. The approach could conceivably be extended to smaller vehicles as well, such as station wagons and sedans. Government involvement can often reduce or eliminate regulatory problems and other obstacles faced by private third-party systems. Such a program may make sense as a self-supporting permanent conservation measure. It may be appropriate to begin a pilot project as a conservation measure and to purchase a reserve fleet of vans as a contingency.

Actor: Major Employers

Major employers — that is, those companies, agencies, and other institutions who employ large numbers of people at single work sites — are in a unique position to promote the use and development of transit, paratransit, and ridesharing for the journey to work. The actions briefly discussed in this section illustrate only some of the things major employers should consider doing in preparation for, or in response to, a fuel-supply emergency. Some of the actions described here will make sense even in the absence of an acute crisis as long-term conservation actions. Many of the actions described will not only help society by promoting fuel conservation, but will also help employees and employers themselves during a shortage by facilitating job access, improving morale and productivity, or reducing costs (e.g., for travel and parking lot expansion). Five general types of actions are identified below, but they are not meant to be exhaustive. One major type not included comprises those actions that save transportation fuel by reducing the amount of work-related travel (e.g., substitution of telecommunications for travel, satellite work centres, options for increased work at home). These options should also be considered by those employers who could implement such strategies.

1. Information, Education, Organization

Employers can establish a basis for increased promotion and utilization of high-occupancy modes by gathering information, educating employees, and working cooperatively with other employers. Some specific actions which might be undertaken include:

- Surveying employees to determine where a potential exists for high-occupancy vehicle commuting.
- Setting up a "Commuting Information Office," with transit schedules and maps, park-and-ride locations, carpool matching board, and publicity on special services and incentives.
- Using the company newsletter, personal letter, etc., to provide information on carpooling programs and assist people who are seeking or offering rides.
- Organizing with nearby employers to identify special needs and implementing mutually beneficial services.

Actions such as these will be useful during a fuel emergency. However, they are also worthwhile in normal times as a response to rising fuel prices, parking space problems, or plant relocations. Communication efforts will need to be expanded as more employees seek information and assistance. For a short-term crisis, employers should probably focus on expanding existing initiatives rather than creating new ones. Commuter behavioural change in response to a short-term crisis may continue after the immediate crisis subsides, to the benefit of all.

2. Actions to Promote Use of Carpools

The high-occupancy mode with the greatest potential for large and rapid expansion in a fuel emergency is the carpool. Employers are particularly able to facilitate such expansion. Some specific actions include:

- Implementing and promoting a carpool program among employees (personal communications from high-ranking company officials will be particularly helpful).
- Providing preferential parking or other parking-related incentives for carpools.
- Acquiring carpool matching software to do in-house matching.
- Allowing company fleet vehicles to carry three or more employees to work.

Actions to promote carpooling may make sense as a conservation measure for a variety of reasons, largely economic, which do not relate specifically to energy emergencies. Indeed, it may be appropriate to begin planning for emergency-response actions before the need arises. Should a severe crisis occur, transit and auxiliary transit capacity will be totally filled, vans may be hard to obtain, and carpools may be the only available method of increasing average vehicle occupancy for the work trip.

3. Actions to Promote Use of Vanpools

Vanpools can be a very effective mechanism for conserving gasoline consumed in commuter travel. Employers are in the best position to promote vanpool use by purchasing vans, organizing ride-matching programs, providing preferential parking for vanpools, and allowing employees who drive eight or more commuters to work to utilize the vans for personal travel on weekends. Such programs cost the employer little, if anything, because passengers pay a monthly fare which covers the costs of the system. Some companies have succeeded in reducing employee vehicle-miles of travel to and from work by up to 35% and have reduced their parking space requirements through the promotion of such vanpool programs. Cost-effective vanpools are most feasible where clusters of eight or more employees live some distance from the work site. In some cases, fuel-efficient company-provided automobiles may be appropriate to form ''van''pools of four persons. Companies that do not wish to run their own vanpool programs can have such programs provided by so-called third-party operators.

Promotion of vanpools should be started as a conservation measure for economic or long-term conservation reasons. In addition, because of the lead time required, contingency planning to institute such a program when a fuel shortage occurs should be should done now.

4. Actions to Promote Use of Transit and Paratransit

Employers may promote the use of transit and paratransit by employees for their trip to work in many ways, including the following:

- Distributing (selling) transit passes and participating in transit pass or commuter ticket payroll-deduction programs if these programs are offered by local transit operators and agencies.
- Providing partial or full subsidies for transit passes.
- Initiating shuttle services to nearby transit stops or stations, using company vehicles.
- Organizing charter or subscription services for groups of employees, using local private bus or taxi companies, or company-owned buses driven by employees.
- Cooperating with transit and auxiliary transit operators in staggering work hours or establishing flex-time programs.

Many other possibilities exist. Employers should contact local transportation providers for recommendations.

Transit and paratransit promotion efforts should be begun as ongoing conservation measures. Otherwise, contingency planning should be carried out in coordination with local transit officials, and arrangements should be made to assure service availability under emergency conditions.

5. Incentives and Disincentives

Employers are often in a position to simultaneously apply incentives to use high-occupancy modes and disincentives to single-occupant auto usage. Such actions can be very effective. Examples include:

- Reducing the number of employee parking spaces and / or increasing parking fees.
- Offering ridesharing and transit-riding employees the dollar value of the parking subsidy provided for single-occupant commuters, or imposing a fixed per-day parking charge on all vehicles entering the work site, then returning the proceeds of the charge to each employee equally, regardless of mode of access.
- (In areas served by transit) offering employees the choice of a parking space or a subsidized transit pass.

Such measures could be perceived by employees as punitive and therefore may be difficult to implement. Nevertheless, in some situations they may be the most effective type of action an employer can take. In addition, it should be possible to package incentives in a positive way (i.e., as new benefits) rather than taking away old benefits.

In general, actions such as these will not be beneficial as conservation measures unless an employer wants to make a very strong commitment to ongoing conservation. A crisis may permit the imposition of disincentive-type measures. On the other hand, employees who drive alone may be seen to have enough trouble getting to work without their employers adding to their woes. The crisis itself will generate such strong incentives to seek other means of getting to work that incentives are likely to be meaningless in such a context.

Actor: Providers of Physical Infrastructure

The actors referred to in this section are those public agencies or organizations that have official responsibility for providing and managing physical infrastructure such as streets, highways, traffic signals, and park-and-ride lots. Such actors will typically include one or more of the following:

- the provincial Ministry of Transportation and Communications
- city and town governments
- the county or other regional agency
- transit providers or ridesharing organizers

The role of these agencies in fuel emergencies is important, particularly in providing support for other energy-conservation and contingency initiatives. The provision of adequate park-and-ride facilities and adequate public information can be an effective element of transit, paratransit, and ridesharing (*TPR*) strategies. Priority treatment for high-occupancy vehicles by provision of special lanes or of priority access at traffic signals, ramps, and other congested locations can be essential to the success of *TPR* initiatives. However, such actions may be beyond the control of the agency specifically charged with the responsibility of providing *TPR* services. Thus, the support role played by this actor, while important, will not easily be realized, as it is not likely to be an activity of high priority within the agency. Indeed, the agency is unlikely to receive praise if the support role is played well, while it will receive the anger of that segment of the public which is displeased with the success of the HOV lane, priority traffic signal, and so on. For this reason, very determined efforts will be required to elevate the status and priority of these activities in the relevant agencies.

Provide for Ample Park-and-Ride Locations and Adequate Public Information for Their Use

This goal can be carried out either by public purchase and construction, by part-time leasing of existing church and shopping-centre parking lots, or by a combination of the two. It is highly desirable that planning and implementation activities be carried out to develop an excess supply of park-and-ride capacity which can be made available during emergencies.

During a shortfall, available excess capacity should be publicized; conversely, over-subscribed capacity should not be publicized. Free media publicity is likely to be available because of the emergency. (However, this may not always be the case.) It may be possible to achieve breakthroughs on new park-and-ride locations because of the emergency condition. Identification and establishment of new park-and-ride locations may not be possible in time to be useful for this crisis, but should be pursued for longer-run purposes.

In a more severe situation it may become necessary to set priorities among transit and carpool users who are competing for a limited number of spaces in some locations. The development of auxiliary transit feeder service to some of the park-and-ride locations may begin to make sense.

6.6 Contingency Plan Review

Contingency plans are unique to each city. Conditions and administrative relationships vary from city to city.

Development of a fully workable plan may take several years as responsibilities are defined and specific people or agencies work out procedures. As noted earlier, all actions can start with conservation policies that apply even prior to a fuel shortfall. From that base a contingency plan is easier to develop. Experience with fuel-consumption measurement, implementation, and evaluation can only be gained by taking some action. The contingency plan can then be reviewed and upgraded to be specific to that particular municipality.

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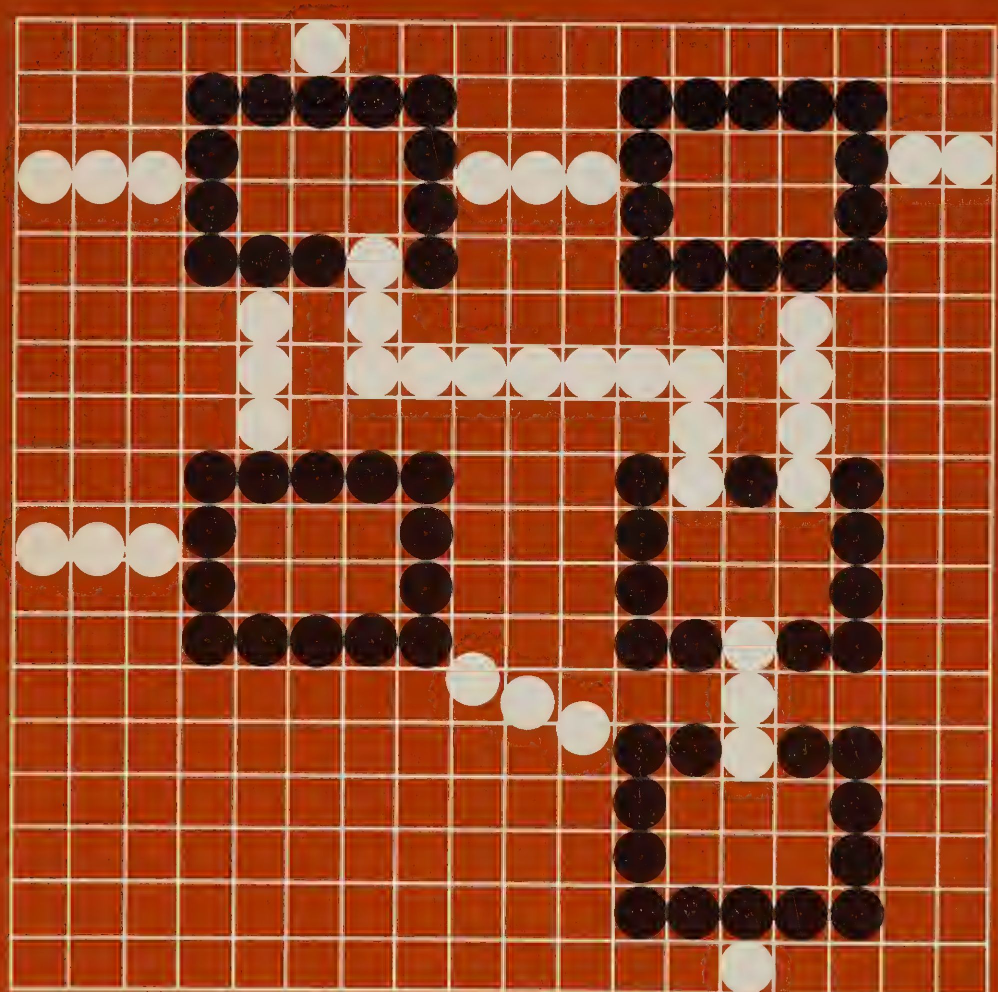
Transportation Energy Analysis Manual

9: Municipal Energy Program Management



The cover design was inspired by GO, the ancient Japanese board game. By applying analytical judgement and strategic skill the GO master accurately predicts possible outcomes and initiates a progression of steps designed to yield the desired result.

TEAM
Transportation Energy Analysis Manual

9: Municipal Energy Program Management

Published in Consultation with
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Preface

The purpose of the **Transportation Energy Analysis Manual (TEAM)** is to guide municipal decision-makers and transportation professionals to those actions which can effectively reduce energy consumption within the municipality. The Manual is organized into ten chapters, which outline the principal technical ways to conserve energy through transportation improvements.

Potential users of the Manual are widespread and varied. They come from the private sector and from all governmental levels concerned with transportation and energy decision-making. The principal focus is at the local and regional-municipality level. This is the crucial public-sector level because these decision-makers deal with the day-to-day activities of thousands of citizens residing within their municipalities. Energy conservation is an on-going, everyday affair, and the municipality is directly involved.

The **Transportation Energy Analysis Manual** will consist of chapters on the subject areas listed below. These will be updated as considered necessary.

1. Overview and Summary
2. Street-System Operation
3. Transit Service
4. Ridesharing
5. Travel Demand Management
6. Municipal Fleet Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Energy Program Management
10. Energy Analysis Methods

This chapter, **Municipal Energy Program Management**, focuses on and highlights the principles involved in managing transportation energy conservation in a municipal setting.

Additional information on the Manual or any aspect of transportation energy-management can be obtained from the Transportation Energy Management Program (TEMP) office.

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Table of Contents

1 Introduction

The management of energy in a municipality is no different than the management of any other municipal function. It is a matter of planning what is to be done by organizing the manpower and resources to undertake a given program, and then directing and controlling the operations to ensure that the program is achieving the desired results. By following this course of action, significant dollar savings and reductions in energy consumption can be achieved by the municipality.

Energy management does, nevertheless, have its own characteristics because it encompasses the entire spectrum of municipal services. For this reason, a management program that can effectively handle the diverse energy-conservation programs in a municipality has to be flexible in terms of specific procedures. There are a number of basic elements that should be followed, but each office or department must run its own program.

2 Energy Management In A Municipal Organization

Two principal methods can be used to manage municipal energy programs. The first treats energy analysis as "another" item added to the list of functions each operating department of the municipality performs. The second considers energy management as a separate entity to be performed by an "operating department" on its own, reviewing energy impacts in all areas.

Most municipal governments adopt the first method. By contrast, in the federal and provincial settings, the second method is dominant. The basic reason for this difference relates perhaps to scale and relative political importance. In considering the relative significance of energy among the various municipal services delivered to the public, it appears realistic to recommend that municipal governments should manage energy programs according to the first method. Each operating group is then able to assess energy usage without requiring specialized assistance.

In the discussion that follows, the emphasis is placed on managing transportation energy-conservation programs. However, the basic principles outlined are equally applicable to energy-conservation programs in all other sectors of municipal services. (There are other programs covering community energy management and buildings technology. For information on such programs, contact the Ontario Ministry of Energy.)

Regardless of the management format used, coordination and communication are critical features that should be present in any plan.

3 A Management Framework for Energy Conservation

It is important to develop a well-defined management framework for transportation energy conservation. Such a framework consists of steps that should be undertaken in a given sequence to ensure the eventual success of the energy-conservation task. Seven steps have been identified and are described in this section.

The framework should be developed through active cooperation among municipal staff members in conjunction with other interested parties.

The Municipal Transportation Energy Advisory Committee (MTEAC) has taken a leading role in developing and promoting a systematic framework for transportation energy management that can be tailored to the specific requirements of various municipalities. This manual is intended as a guide to assist municipalities to develop and implement such a framework. As experiences are reported they will be passed on to holders of this manual.

3.1 Obtain Commitment of Council

Of paramount importance is the involvement of political representatives and top management. Without such involvement, a full commitment to transportation energy conservation cannot be made.

Often such a commitment must first come from senior staff management and then, through them, from the municipal council. Indeed, without this step, any program to reduce energy use in a municipality will ultimately fail. The municipal council and senior management staff must recognize that transportation energy-conservation programs are important enough to assign staff and commit funds to them. With support, the programs can be successful and will provide beneficial results in the community. The commitment of funds should permit not only the payment of wages and salaries for the time spent on energy-conservation work, but also the hiring of consultants to carry out various specialized evaluation studies. If these steps are not taken, a token commitment will yield second- or third-priority work situtations that waste human resources.

The next natural question is how to get such a commitment. There are various approaches, as outlined below:

- Staff would recognize through their own work experience that there are certain opportunities for energy conservation which, when they are properly identified and estimates of their financial implications are made, could be forwarded to the municipal council for consideration. Thorough documentation will indicate the importance of the recommended action.
- Support may be obtained from higher levels of government (i.e., provincial or federal) by seeking or identifying programs that would be eligible for subsidies from and/or sponsorship by these agencies. Commitment of funds by others indicates that the merits of a program have been studied and are worthy of financial support. This commitment also removes some of the risk for the municipality, at least until some experience is gained.
- Actual experience elsewhere in transportation energy conservation could be documented and quoted, and estimates of dollar savings developed. These could be used as backup facts and figures to support a proposed program under consideration by the municipal council.
- The cost effectiveness of any proposed program must be clearly delineated in both quantitative and qualitative terms. It is in this area perhaps that data contained in this Manual would be of use in describing the impacts of energy measures.

It is important to stress that staff members themselves should be thoroughly committed to the idea of implementing transportation energy-conservation programs within their respective divisions. Without their own solid commitment, it would be difficult to obtain commitment from their municipal council or to produce the desired results during implementation.

Energy conservation nowadays is on everyone's mind. It may not be as difficult a task as some staff members believe to obtain a commitment to it, because most municipal councils are sensitive to this important issue.

Next, it is relevant to establish what form such commitments from a municipal council should take. The form would vary perhaps from one area to another. In one municipal setting, such a commitment could be expressed explicitly as a goal or

objective of the Official Plan of that municipality. In another setting, a policy direction from the municipal council could be handed down to senior staff to employ energy-conservation practices in their everyday programs and as an additional parameter in their evaluation of investment in transportation development projects.

3.2 Assign Responsibilities

Once a clear mandate has been established for transportation energy conservation, it is important to draw the lines of responsibility for energy management. Program responsibility could be given to an individual such as an energy coordinator, to one municipal department, or to a committee established from all departments. All three methods have been used, but whichever is chosen, those people selected should ideally be in a position to affect decisions and policy and should be given the responsibility for achieving results. They must meet regularly and have access to support staff and to all records of the organization relating to energy.

In large municipal organizations, the committee structure might work more effectively, especially if the chairman of such a committee is a senior staff member. Furthermore, the recording secretary and the ''work-horse'' of the committee would be the *energy auditor*, hired perhaps through the Ministry of Energy Municipal Energy Audit Program (MEAP) (administered by the Ministry of Municipal Affairs and Housing). The energy auditor should ideally be able to work with each department as if he were part of it. He would submit reports to the committee that would provide direction for and monitor the results of the energy program.

Without the support of a committee structure, an energy co-ordinator / auditor will be faced with an unnecessarily difficult challenge. He or she may appear on the scene ill-equipped to handle problems, having little knowledge of the organization and no contacts with the senior staff of the operating departments. Looked upon as an outsider, he or she will have difficulty getting all available information. Actual implementation of conservation measures could be even more difficult.

The important functions of the lead person or agency are to:

- chair and record proceedings;
- direct technical effort and provide assistance;
- monitor and maintain active participation of each group or department;
- direct the dissemination of information internally and to the public;
- report to council.

3.3 Define Goals and Objectives

Once authority has been delegated and the lines of responsibility are drawn, the next step in the process is to select the goals and objectives to be achieved. These must be clear and measurable, consisting as much as possible of specific targets. The work plan should consider both of the following areas:

- internal transportation energy management
- external transportation energy management

In the first area, transportation energy-conservation opportunities within the municipality's own operations should be investigated both in the short (non-capital-intensive) and long term. Proper management of this ''internal'' area by the municipal corporation will save taxpayers' dollars in the municipal budget.

In the second area — the ''external'' transportation system — the municipality has an opportunity to provide its citizens with ways of saving energy themselves. Actions that the municipality can influence, as in the area of travel-demand modification and transportation-system supply, are examined again in the short and long terms. The way that each of the actions or opportunities relates to the goals and objectives of the program should be spelled out.

Some examples of clear and measurable goals include:

- reducing energy consumption by municipal vehicles by *x* % over *y* years;
- reviewing the usage of all municipal vehicles for fuel efficiency during the next *y* years;
- educating *x* % of all drivers of municipal vehicles each year.

3.4 Define Programs / Projects

This step is a preliminary screening to identify all potential energy-conservation measures that may be applicable. Transportation energy consumption is covered in this Manual under six major chapters. These are:

- street-system improvements,
- transit-system improvements,
- ridesharing,
- travel demand management,
- fleet management,
- construction and maintenance.

A list of short- and long-range projects for both internal and external applications could be drawn up. Input to this list should come from all levels of the departments represented on the committee. From such a list, priorities could be established for those projects that would directly address the goals and objectives previously established. Undoubtedly the list will contain projects presenting

problems and possible trade-offs. This is where sound judgment based on extensive experience must be exercised. This Manual will assist staff in developing such projects and evaluating trade-offs.

3.5 Establish a Data Base

Projects receiving top priority will constitute the immediate energy program. For these, an energy data base must be established. Such a base should include data from all studies and other technical information available to date. It is important to obtain actual figures of transportation energy use in a municipality (internal or external) in order to determine where savings could be made. This information is also essential in order to compare the results of any action taken to reduce transportation energy use.

Ideally, these facts and figures should come from the municipality's own records. However, information from and the experience of others might also be considered. Of particular significance are studies and technical information available from the Ministry of Energy, the Ministry of Transportation and Communications, and their provincial-municipal advisory committees. These agencies have compiled a tremendous amount of data which can be used by any municipality interested in reducing transportation energy consumption.

Furthermore, it should be a fundamental duty of the energy auditor to assemble transportation energy data for that municipality to supplement those developed elsewhere. The data collected should be both technical and non-technical, qualitative and quantitative. Due caution must be exercised while compiling these data, as it is very easy to double-count costs or benefits.

3.6 Prepare Implementation Plan and Involve Others

Based on the results of the previous steps, it can now be ascertained which project(s) or plan(s) have the highest potential for energy conservation according to the goals and objectives set forth. Detailed studies and a cost-effectiveness evaluation are necessary. A plan of action must be developed to determine how best to implement the opportunities that have been identified and the priorities that have been set. Absolute values of energy savings are important, but cost-effectiveness also has to be considered. Low cost and high public acceptance can make a measure worthy of implementation even with low energy savings.

Program selection should also take into account the added benefit in energy savings that accrues when measures are complementary. Savings with combined implementation can be greater than with individual use.

A key element in the success of any transportation energy program is to ensure not only that the municipal staff understands and supports the program, but also that the public is made aware of the reasons for the program and the results which can be achieved. This is a most difficult area, as both employees and the public can be resistant to change, but support from both groups is vital for the success of any program.

3.7 Monitor the Program

Once the program is under way, it is important to monitor its progress constantly and to tabulate the results of the various measures undertaken. These results can be used to determine whether the program is working as planned or whether alternatives are required. Results should also be published and made available to both staff and the public so that they are able to see that the steps taken to reduce energy consumption are working. This approach tends to generate greater enthusiasm and support for other energy-conservation measures. Feedback from users of municipal services and from municipal departments is also important. Measures and changes that are justified from an energy-conservation viewpoint may have features that are unacceptable for operational, economic, or political reasons. This aspect should not preclude taking action, but rather calls for a close scrutiny of major changes and more intensive investigation.

4 Experience of Ontario Municipalities

As noted in section 2, it is possible to organize the management of municipal energy programs in a variety of ways depending on particular circumstances. Generally, the practice of adding energy-conservation functions to the responsibilities of existing municipal departments is the most realistic and expedient strategy. When functions are split between departments, however, an effective means to coordinate activities must be implemented.

4.1 A Representative Approach

A representative approach to meeting the coordination challenge described above is illustrated by the Energy Management Committee of the Regional Municipality of Waterloo. The committee's composition is as follows:

- Manager of Laboratory Services, Chairman
- Energy Audit Officer, Secretary
- Director of Engineering Operations
- Director of Roads and Traffic
- Director of Accounting
- Manager of Plant and Site Operations
- Senior Planner
- Manager of Buildings and Properties
- Senior Buyer
- Assistant Head of Day Care
- Property Supervisor, Regional Police Force
- Inspector, Regional Police Force

The committee is chaired by a senior management employee of the Engineering Department — a line department responsible for the delivery and implementation of energy-conservation measures. As well, the committee reports to Regional Council through the Engineering Committee, a standing committee of Regional Council. These arrangements facilitate and encourage "follow through." Representation on the committee encompasses all municipal functions where an opportunity to develop or implement conservation programs exists. The Waterloo committee, as can be noted above, has senior representatives from a wide range of related municipal interests including buildings and other structures, transportation, finance, purchasing, planning, police, and fleet services. The Municipal Energy Audit Officer is a key member of this team.

A recent typical project of the committee is the propane conversion program for regional vehicles. In order to initiate this program, a sub-committee of the main committee was established to investigate the opportunities for and the cost and benefits of such a conversion program. The Director of Roads and Traffic was appointed as sub-committee chairman and the committee itself was composed of the Senior Buyer (Purchasing) and the Fleet Superintendent and officials of the regional police department on an as "required" basis. It is useful to note that such sub-committees often involve resources outside the main coordinating committee in order to ensure maximum input for their task and a broad base of support for recommendations related to the program being developed. Such consultation should be encouraged.

The Propane Conversion Sub-Committee carried out a considerable amount of research regarding alternative conversion technologies, fuel supply and storage, and fleet-user concerns, and conducted a thorough set of investigations involving costs, benefits, and payback periods. Throughout, the emphasis was on both energy conservation and cost reduction. The importance of thorough investigation and analysis cannot be overemphasized.

The sub-committee's report was subsequently presented to the Energy Management Committee, which endorsed it. At the request of the committee, it was then endorsed by the Commissioners of Finance and of Engineering. With such broad staff support, the report was well received by the Regional Engineering Committee and by Regional Council. This process of endorsement thus paved the way for the smooth implementation of the project and generated a receptive atmosphere for future staff proposals.

After more than a year of operation, it can be concluded that the municipal model exemplified by the Regional Waterloo committee is both workable and effective. The Regional Municipality of Waterloo, an urban/rural municipality comprising three cities and four surrounding townships, has a population of approximately 320 000 people. While its jurisdictional responsibilities differ in some ways from those of other regional municipalities and other municipal corporations, it nonetheless represents a fairly average example of a medium-sized Ontario municipality.

4.2 Other Approaches

It is not suggested that the Waterloo energy-management model be duplicated in all municipalities. There are, of course, variations between municipalities in many important details. Innovative approaches which build on examples of proven success and respond to unique local circumstances are to be encouraged.

An interesting innovation which the Regional Municipality of Hamilton-Wentworth introduced into the structure of its energy-conservation committee was the concept of a rotating chairman. With the Engineering, Social Services, Finance, and Planning departments all represented by their directors or other senior staff, it was decided to rotate the chairmanship duties on a yearly basis. In the first few years of the program, this practice gave two of the senior managers a turn at being responsible for directing energy-conservation activity in the region and tended to increase interdepartmental cooperation. More recently, in keeping with the changing nature of the task, this committee has a greater working-level representation and includes personnel from the regional police, homes for the aged, and the fleet and transit operations. A full-time Energy Coordinator now plays a large role in the committee's quarterly deliberations.

Metropolitan Toronto uses a two-tiered committee structure to implement its program. A 12-member Energy Conservation Working Committee, comprising personnel responsible for conservation in their departments, meets monthly to coordinate activities and share information. Every four or five months, the department heads involved meet as another committee to monitor progress, plan future efforts, and discuss policy implications. An Energy Conservation Manager provides staff support to these two committee structures.

Ottawa-Carleton is using departmental task forces to ensure implementation of energy-conservation measures. An in-house Energy Conservation Committee, made up of senior professionals in the Transportation and Works departments, the homes for the aged, and the transit agencies, has developed a set of detailed recommendations for each department. The task forces have responsibility for implementing the proposed measures, monitoring progress, and reporting back to the committee.

Hastings County covers a large rural area comprising twenty-seven eastern Ontario municipalities. Like many municipalities, it appointed an Energy Conservation Coordinator (1979) who, in addition to his existing duties, was to raise awareness of energy-saving techniques and possibilities. Two years later, when the county hired a full-time Energy Auditor under the Municipal Energy Audit Program (MEAP) administered by the Ontario Ministries of Energy and of Municipal Affairs and Housing, it established an Energy Committee made up of three councillors to oversee and support the energy-conservation effort. This approach has helped ensure a high level of participation by member municipalities (25 out of 27 are active) by both increasing the level of conservation activity and making it more viable.

5 Conclusions

A simple and pragmatic discussion of the principles involved in managing transportation energy conservation in a municipal setting has been presented. The key steps are outlined; however, these should be adopted judiciously to fit the individual requirements of a given municipality. To this end, all municipalities participating in and implementing various plans for energy conservation should attempt to document their experiences and to exchange the knowledge gained of the strong points of their programs and any pitfalls encountered while carrying them out.

The principles of managing energy programs are not new, but the scale of the issues involved requires that province-wide (and in fact nation-wide) efforts be expended to establish appropriately tailored energy-management strategies that will improve the efficiency of our energy use.

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6. Municipal Fleet Management
7. Road Construction and Maintenance
8. Contingency Planning
9. Municipal Energy Program Management
10. Energy Analysis Methods

This chapter, **Energy Analysis Methods**, highlights the steps and principles to be followed in implementing a transportation improvement program focused on mobility and energy needs.

Additional information on the Manual or on any aspect of transportation energy management can be obtained from the Transportation Energy Management Program (TEMP) office.

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Table of Contents

1 General Guidelines

This chapter shows how a community can develop an energy-sensitive transportation improvement program. It gives the steps and principles to be followed in developing and assessing improvements in response to mobility and energy needs. It provides both a context and a synthesis for other chapters in this Manual.

The following principles underlie a transportation improvement program:

- Improvements should address both mobility and energy. They should focus on actual or perceived problems and solve these problems in ways that conserve energy and also improve movement. Good traffic engineering is generally consistent with energy conservation.
- Improvements should fit community-specific conditions. What works in Toronto may not in Kitchener. Stated another way, improvements should be reasonable to the travellers affected, surrounding neighbourhoods, and the whole community. Every community cannot implement every transportation energy-management action.
- Energy-improvement opportunities should be developed as part of a community's comprehensive short-term and long-range planning.
- The scale of energy savings of many individual actions is small and is hard to calculate. Yet, such actions may be desirable because (1) collectively they save energy and (2) they have other benefits.
- The travel-time savings associated with many transportation improvements are easiest to identify. Benefits from changes in travel mode or reductions in peak-period travel are more difficult to quantify. Energy savings usually accompany savings in travel time.
- From an energy perspective, it is desirable to minimize (1) the fuel consumed per vehicle-minute or vehicle-kilometre travelled (VKT), (2) the number of kilometres or minutes required to travel between two places, and (3) the number of vehicles that make the trip. It is also desirable to maximize the number of people using any transport vehicle.
- The energy savings shown in the various chapters of this Manual are representative of Canadian experience. However, they may vary according to specific local conditions.

2 Overview of Program Planning Procedures

The key planning steps in identifying, screening, assessing, and selecting improvements are listed in Table 10.1. These steps, as noted, flow out of the problems and objectives in any given area.

Step 1: Analyze the Problem and its Setting

The first step is to identify clearly the specific transportation and/or energy problem to be addressed. Is it arterial street congestion along the main artery leading to the city centre? Is it inadequate transit service and hence excessive car trips within a growing residential area? Is it ineffective use of the existing municipal car fleet from an energy perspective?

A field reconnaissance and/or ''base conditions analysis'' may provide the specific data needed to answer these questions and pinpoint problems.

Step 2: Identify Likely Solutions

Once the problems are identified, the analyst should look for solutions that could help solve the problems, from both transportation and energy standpoints. It is necessary to identify the ''scale'' of the solutions — for instance, single intersection, entire street, major employment centre, or entire region. This assessment will make it possible to bring appropriate agencies into the planning process and to assess the likely range of impacts.

Step 3: Screen Actions

The proposed actions should be screened to see if they are realistic in terms of actual land uses, the characteristics of the transportation system, transport needs, and energy effectiveness. This screening may entail reviewing similar situations in the same town, or in other communities. It may also involve using ''conditions of applicability'' based on the collective experiences of other communities to screen out obviously inappropriate measures. For example, a bus lane would not be appropriate along a section of road without either buses or congestion.

Table 10.1

Key Planning Steps

1. Analyze the problem and its setting.
2. Identify likely transportation energy-management actions.
3. Screen actions according to 'Conditions of Applicability.'
4. Assess applicable actions.
   - vehicle trip reduction
   - travel time savings
   - capacity changes
   - energy savings
   - costs
   - cost effectiveness
5. Assess qualitative impacts
   - public opinion/response
   - merchant attitudes/needs
   - operational viabilities
6. Combine actions into groups of related actions and re-assess impacts.
7. Develop improvement program.
8. Plan to measure performance and build in feedback loop.

Step 4: Assess Performance

Actions that survive the screening process should be further analyzed in terms of how well they could solve the problems. Such an analysis should focus on performance measures that influence transportation service, and in turn affect energy consumption. The choice of performance measures will vary according to specific circumstances and actions, but will normally include:

- system usage — number of vehicles and person trips by mode of travel (i.e., transit ridership, car occupancy, traffic volumes, VKT),
- system capacity (vehicle and person),
- service quality (travel times, delays, VKT),
- accidents,
- costs (capital, operating, and maintenance).

These measures are usually directly computed. Fuel consumption and, where desired, vehicle emissions, can then be derived. The formulas and techniques are detailed in the appropriate chapters of this Manual. Costs should be compared with ''benefits'' to see how effective the measures are, especially in energy terms.

Step 5: Assess Other Impacts

At this stage, other relevant factors should be analyzed. Is the solution really workable? Does it reflect community preferences? Will it benefit or adversely affect the surrounding businesses and activities?

Step 6: Combine Actions

In many cases it will be necessary to combine related actions into "groups" to avoid transferring problems or to attain perceptible time and / or energy savings. The various impacts of these groups should be reassessed as needed.

Step 7: Develop Improvement Program

The last step is to develop a staged improvement program that brings together recommended actions for each time period. This program should include schedules for a staged implementation, including costs, responsibilities, and recommendations for supportive actions by various agencies. Assignment of priorities should reflect:

- degree of problem and need,
- likely energy and mobility benefits,
- coordination with other projects,
- costs.

The sections that follow describe some of these steps in greater detail.

3 Description of Procedures

3.1 Identify Problems

Implementing transportation energy-management actions calls for selective improvements that are keyed to problems. In many respects the decisions on what to implement are actually made when the problems are identified and assessed. Moreover, many transportation and energy problems are sufficiently important to have resources allocated for their solution in advance of proposed actions.

It is important therefore to identify problems carefully at the outset of any program and to decide which problems, or groups of problems, should be alleviated. Problems can be identified by (1) reconnaissance and observation; (2) application of performance standards; (3) private-sector and citizen requests; and (4) financial analysis.

1. *Field reconnaissance*. A field inspection of traffic and transit operating conditions, especially in the peak periods, is indispensable for both identifying problems and formulating solutions. Such investigations will pinpoint the type, location, causes, and extent of peak-hour traffic congestion and queues, street discontinuities, illegal parking practices, areas without transit service, and similar site-specific deficiencies that affect movement and fuel consumption. They will give an integrated picture of where the existing transport system falls short in an operational and physical sense. Results can be shown graphically on a map of the street, corridors, or area under consideration.
2. *Performance analysis*. Analysis of data that describe the operations or performance of the existing transport system can complement the reconnaissance. Data such as traffic volumes, travel times and delays, bus and rail load factors, maximum waiting times, parking accumulation, turnover, duration, and transit service coverage are routinely collected. The data can be compared to standards such as minimum desired travel speeds (or minutes per mile), volume-to-capacity ratios (or level of service), or transit service, and deficiencies can be quantified. It may be possible to develop, for example, an "energy profile" for a given street that shows the Megajoules consumed per vehicle- or person-kilometre by section of route.

   Again, results can be mapped to show clearly key interrelationships.
3. *Requests and complaints*. Requests from staff, other public agencies, elected officials, and developers may be valuable in identifying problems. Similarly, complaints received directly from the community may prove useful. While all requests may not, in themselves, generate improvements, they may at least help to highlight perceived problems that need attention.
4. *Financial analysis*. Cost/revenue comparisons are useful to identify problems such as inadequate pricing, excessive transit service, or ineffective management. For example, a very lightly used bus route that incurs a large deficit may also involve a large energy expenditure per person carried; changing the service may save both money and fuel.

Many transportation problems can be identified, reviewed, and assessed at set intervals as part of a community's regular monitoring process. Others may require special assessments as part of a program. The task of sorting out and assessing such problems is not an easy one. A number of questions must be clearly answered, both in general and energy-conservation terms.

- Is the perceived transportation problem a real one? Is it a common or infrequent one?
- Does the problem require attention now, or can it be deferred for a few years?
- Is the observed problem actually a symptom of a more fundamental one? (For example, high energy consumption and delays at a given intersection may be caused by a major street discontinuity and offset.)
- What related transportation problems are likely to occur in the near future? (For example, a new office park may be built along an already congested roadway.)
- Will the solution introduce new problems into a nearby area? (For example, a street widening may shift congestion to an intersection along a part of the street that was not widened.)
- Is the problem (for example, a bottleneck on the approach to the Central Business District or CBD) a strategic one — that is, does it adversely affect the main transportation arteries?
- At what scale should the problem(s) be addressed and what is the appropriate study area?

Is it an intersection? the CBD? the entire community?

- Are special data-collection or analysis efforts needed; if so, are staff and funds available?
- Can low-cost ''management'' actions solve the problem or set of problems? Or are capital-intensive improvements needed?
- What types of solutions can best solve the problem, and what factors should be analyzed in selecting and assessing the solution?

Two points are significant: (1) the identification and assessment of transportation problems is concerned with more than energy consumption alone — it extends to the issues of mobility, costs, and environmental impacts as well; (2) there is a fine line between problem assessment and solution assessment — these steps may proceed either concurrently or sequentially.

3.2 Select and Screen Improvements

Proposed improvements should be both problem- and city-specific. The many differences in local land-use patterns, transportation system features, and community attitudes make the prescription of a single set of energy-conservation actions impractical. As a means of selecting, screening, and assessing improvements, a two-step approach is recommended. First, actions should be screened on the basis of their general applicability and preliminary estimates of effectiveness; second, detailed analyses should determine their specific impacts.

Accordingly, generalized ''conditions of application'' have been developed for various energy-conservation factors, based on past experience in the United States and Canada. They include two main categories:

- *Land-use and environmental conditions* reflect the type and intensity of urban land use, such as central-area employment. For example, major employment concentrations are needed before a traffic restraint or ridesharing program is implemented. The presence of a major outlying residential market that can be served by additional express bus transit is another example.
- *Transportation conditions* relate to the type and level of transportation service. Examples include the number of buses along a street; car and bus operating speeds; and the distribution of trips between car and transit. Implementing a bus lane, for example, presupposes a minimum level of bus loading and peak-hour congestion.

Together these factors provide guidelines for realistic and ''cost-effective'' application of various energy-saving transportation actions. Bus priority lanes on freeways, for example, require certain combinations of freeway design, traffic congestion, traffic flow patterns, and bus use. Staggered work hours and carpool programs work best where large employers exist.

Figure 10.1 shows the regions of influence for selected actions based upon employment and population density. Traffic-engineering actions will be appropriate in all urban areas; in contrast, actions that limit or restrain vehicle use will be applicable only where high employment densities exist — for instance, Central Toronto or Ottawa.

Figure 10.1

Generalized Applicability of Energy-Conservation Measures

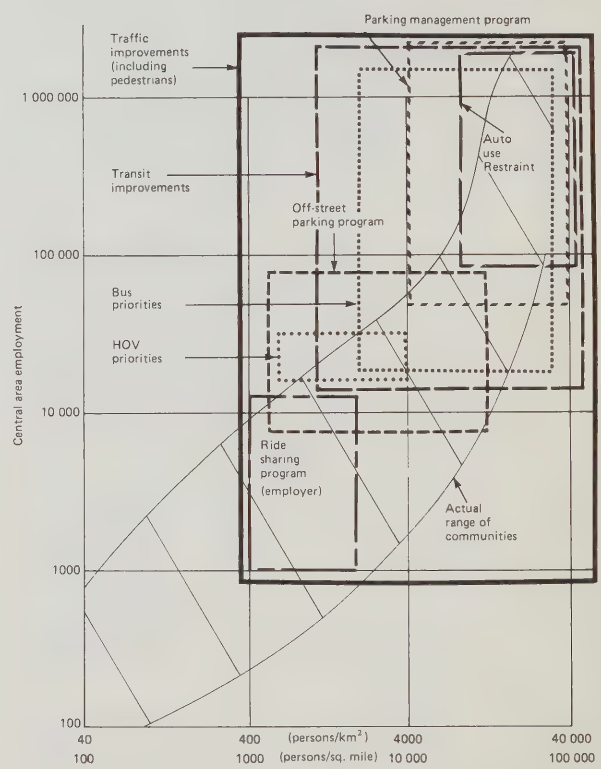

Table 10.2 summarizes the broad, general conditions that must be present for selected types of energy-conservation measures to be successful. Appendix table A.6 gives specific conditions of applicability for a broad range of transportation energy-conservation measures. In an effort to provide guidance to communities, the various conditions listed in this table have been quantified where possible. They show ''what works where,'' thereby enabling inappropriate actions to be

Table 10.2

Generalized Application of Selected Energy-Conservation Measures

Measure	Principal Conditions: Land use and environment	Principal Conditions: Transportation
Demand management		
Variable work hours	Large employment concentrations	High transit use; overcrowded transit lines
Ridesharing	Large employment concentrations; reduce VKT	Low transit use
Area licenses	Large employment concentrations	Most trips to area by transit; street congestion; bypass routes available for through traffic
Auto-free restricted zones	Major employment and pedestrian concentrations; need to reduce VKT	High transit use
Parking supply constraints	Need to reduce VKT	High transit use; congestion; street capacity constraints
Residential parking permits	Inadequate off-street parking space; high residential density	—
Street Use Efficiency		
General traffic improvements		Street capacity deficiencies; congestion points
Express streets, reversible lanes		Arterial congestion: alternative routes available; directional flow imbalance
Priority High-Occupancy Vehicle (HOV) treatment		Congestion on arterials; low transit use in corridor
Park-and-ride	Available land; large employment concentration in CBD; generally, low residential densities	Limited transit in tributary area; radial road capacity constraints; available express transit; minimum competition to established transit system
Bus lanes (bus-only roads or contra-flow)		Congestion in corridor; specified number of buses; suitable geometry
Bus lanes / priorities - city streets		Street congestion; specified number of buses
Pedestrian malls (or bus-pedestrian malls)	Pedestrian concentrations; retail frontage	Ability to provide essential services and bypass routes
Curb loading zones for trucks	Commercial frontage	Curb lanes blocked by parked cars
Transit service		
Additional express service	Major markets along outlying parts of transit lines	Imbalances between service provided and ridership; track availability; ''transportation poor'' areas; street corridor congestion
Service expansion	Areas of growing populations or without transit service	Street-system congestion
Service coordination		Bus-rail services to same or complementary areas
Paratransit	Low residential densities	No transit or limited transit in corridor; limited auto ownership

quickly screened from further consideration.

- Actions such as traffic-engineering improvements and transit-service coordination are broadly applicable.
- Actions that restrain or reduce vehicle use (toll and parking fees, auto-free zones) presuppose (1) high employment densities in the city centre; (2) availability of express transit (e.g., subway); (3) a high dependence on public transit; and (4) inadequate street and parking capacity. They will, therefore, be limited to central areas of larger cities.

3.3 Analyze Impacts

Specific methods of estimating the energy impacts of transportation energy-conserving actions are set forth in the various chapters of this Manual. This section reviews the general approaches, gives examples, and presents the underlying philosophy and rationale for such actions. Simply stated, it is usually necessary to:

- estimate changes in transportation system performance — as measured by the number, length, mode, loading, and travel time of trips;
- translate these changes into energy savings;
- assess the corollary effects and costs involved.

Energy Accounting Concept

The energy accounting system should consider both direct and indirect energy. Direct energy is that used to propel a vehicle. Indirect energy is that consumed during manufacture of materials, construction of infrastructure (for example, highways and guideways), and maintenance activities. Indirect energy represents an investment in facilities and vehicles that may, in fact, reduce annual direct consumption of energy in the future.

An energy impact analysis should estimate annual energy costs and savings. An "energy accounting system" should quantify all types of energy expended, especially where major transportation projects such as a new subway or expressway are considered. However, for "transportation system management" (TSM) actions, where only minor construction is required, direct-energy comparisons normally will be sufficient.

The accounting system should compare "before and after" conditions to determine the net change in energy for each impacting group of travellers or road users. For example, a reversible lane on a city street would likely save motorists fuel in the heavy direction of travel, but also would likely increase fuel consumption in the off-peak direction. From an energy perspective, it is necessary to estimate the net gain.

From an energy perspective, a "build" decision is justified when the annual direct-energy savings of a project outweighs the sum of annual indirect-energy maintenance costs and the annualized construction cost.

Almost every type of TSM action has some negative impacts or "disbenefits" that directly or indirectly should be included in the assessment process. When the positive benefits outweigh the negative impacts, the actions should be implemented. A bus-only street, for example, would save buses time and, if long enough, reduce operating costs; however, it could increase congestion for automobile traffic. In such a case, it is important to analyze (1) the net person-minutes saved; (2) the changes in fuel consumed; and (3) the costs involved.

Direct Energy Estimate

Transportation energy consumption largely depends on the number, length, and speed of vehicle-trips, on vehicle loads, and on the engine efficiencies of buses, cars, and trucks. For travel without any stops, fuel used can be calculated from the fuel consumption rate for a vehicle. For stop-and-go travel, the fuel consumed per vehicle-kilometre under urban conditions is directly proportional to the minutes required to travel that kilometre. Thus, travel time savings become synonymous with energy savings.

- Energy consumption per vehicle-kilometre on urban roads and streets can be approximated by the following relationship:

  $$f = a + bt$$

  Where:

  a and b are constants that relate to engine efficiency, t=minutes/kilometre of travel time (t≥=1), and f=litres of fuel per vehicle-kilometre.

- The energy consumed over a given section of roadway weights the preceding formula by the number of miles of road and the number of vehicle-trips using this section.

  $$F = NLf$$

  Where:

  N=number of vehicles in designated time period, L=length of road, and F=litres consumed.

- A simplified formula for urban conditions where average speed does not exceed 60 km/h is the following:

  $$F = \frac{(100.4D + 63T)N}{1000}$$

- Where the volumes and travel times over a section of roadway vary, formula 2 should be applied to each section:

  $$F = F_1 + F_2 \ldots + F_n$$

Forms of Energy Savings

Three basic types of impact result from TSM improvements:

- trip cancellation
- mode diversion
- improved trip-making efficiency.

Trip cancellation and mode diversion affect the *N* in the formulas, while improved trip-making efficiency affects the *t*, or, in the case of motor-vehicle improvements, the coefficients *a* and *b*. Each of these impacts may be positive or negative depending upon specific actions.

- *Trip cancellation* refers to the reduction or elimination of person-trips or vehicle-trips through land-use planning (e.g., clustered high-density developments) or demand management. Examples include high fuel rationing, travel price increases, garage closures, or auto-restricted zones.

  This type of benefit is the most difficult to measure because there are relatively few real-world experiences to draw upon. Since most people travel for some gainful reason, trips not made to the city centre will probably be made to some other location. Actions that ''manage transportation demand'' will achieve some combination of mode diversion, trip cancellation, and trip diversion.
- *Mode diversion* refers to the shift of travel from car driver to car passenger, or from car to transit. It may occur where carpool programs, park-and-ride systems, extensive bus-priority actions, or automobile-use disincentives are implemented.
- *Improved trip-making efficiency* refers to shorter trip times that result from transit and traffic operations changes. Peak-hour parking restrictions and turn controls, one-way-street systems, and coordinated traffic-signal systems would increase travel speeds and conserve energy.

In addition to TSM actions, fuel can be saved through improved driving habits and vehicle maintenance. Construction and road maintenance practices can affect the indirect energy consumption rate as well as having an impact on vehicle performance and therefore on direct-energy consumption rates.

Effectiveness of energy-conservation actions —Experiences in implementing transportation system management and transportation energy-conservation actions provide broad general guidelines for likely effectiveness. This past experience is framed in the light of what can be expected in Ontario municipalities and is summarized in Table 10.3.

Care should be exercised in applying these reported effectiveness values. Local and regional municipalities may experience widely variable results in implementing similar strategies. Local circumstances (for instance, geography, demography, the extent of existing transit) and the receptivity of citizens to recommended actions can yield significant differences.

Actions that apply to a larger impact population generally produce greater energy savings (for example, improving the fuel efficiency of new cars by 10%). Traffic-engineering improvements on a specific road may provide substantial travel-time and safety benefits, but the energy savings would be realized only from travellers on the road, and their regional impact would be limited.

Actions that alleviate extensive traffic congestion will save more energy than those that address less congested situations. This is because the amount of energy to be saved depends upon the amount of energy consumption that existed before the improvement. An increase in average speed from 10 to 15 kilometres per hour will save far more energy than an increase from 40 to 45 km/h.

Regulatory actions may save more energy than voluntary actions, but they normally will receive less community support and will be less likely to be realized.

Energy-analysis procedures — The energy analysis procedures require that five basic steps be executed:

1. Define scale and type of impact.
2. Choose applicable performance measures.
3. Estimate ''before'' and ''after'' conditions.
4. Calculate changes in energy consumption.
5. Compare costs and benefits.

Some features of this approach include:

- clear definition of a principal impact population as the focus for evaluation;
- use of a small number of performance measures;
- keying analysis to time, distance, ridership relationships;
- consideration of secondary impacts only when they are likely to change project decisions.

Step 1: Define scale and type of impact

The scale of impacts, group affected, and type of impact will depend upon the specific actions. A new subway line, for example, will have far broader impacts over a larger geographic area than a single intersection improvement. In all cases, the affected groups should include both those who benefit and those who experience negative effects.

- The geographic scale of impact may include the entire region, the downtown area, a residential

Table 10.3

Energy-Conservation Measures and Savings

Transportation programs	Conservation measures	Potential energy saving	Description	Transportation impact
Internal municipal energy programs	Fleet management	25-30% of fleet consumption depending on base consumption	Municipally controlled automobiles, trucks, graders, and other equipment *as well as* transit and paratransit fleets; energy consumption optimized through maintenance activities	Transportation impact limited to applicable fleet. Region-wide impacts are largely felt through demonstration or example to the general public.
	Vehicle purchasing		Vehicles are appropriately sized to respond to design load and function and minimize fuel consumption per unit of work output.	
	Driver training		Equipment must be properly handled to achieve optimum results for which it is designed and maintained. Sophisticated equipment also requires thorough training in proper application and use.	
Transit improvements (The applicability of transit improvements is limited by the availability of transit vehicles to assure the transit burden.)	Park-and-ride	0.5 to 1%	Encourage multi-modal transfer to either high-occupancy vehicle carpool or to transit-line haul (or express) vehicle. Applicable in moderate and low-density areas 15 km or more from major employment centers. Low cost offers favourable cost effectiveness.	Increases load factors of HOV.
	Express service	Variable (0.2 to 1%)	Offers no-stop service for transit users, decreasing travel time, especially when implemented in conjunction with HOV or bus preferential treatments.	Increases speed, thus decreasing transit-to-automobile travel time ratio; may reduce transit operating costs.
	Service expansion	0.5 to 3%	Extension of routes or decreased headways provide alternative transportation service to areas that were previously automobile-dependent or experienced low service thresholds.	Improves transit accessibility.
	Fare incentives	0.5 to 1%	Fare reductions applied to off-peak, prepayment, special classification transit uses.	Reduces transit cost, diverting person trips from the automobile; may increase net costs of service.

Table 10.3 (Continued)

Transportation programs	Conservation measures	Potential energy saving	Description	Transportation impact
Ridesharing promotion	Employer-based	2 to 4%	Applied with major regional employers, involves matching of riders, preferential treatment, transit subsidy, etc.	Increased auto occupancy - fewer vehicle trips
	Area-wide promotion	3 to 5%	Involves advertising, marketing, public awareness, manual / computer matching, preferential parking. Greatest applicability is in small cities where employers are less than 350.	Increased auto occupancy - fewer vehicle trips
	Public broker	Variable	Provides active agency / organization support for employer-based and area-wide coordination efforts. Coordinates full range of activities including paratransit options.	Increased auto occupancy - fewer vehicle trips
Street system improvement	HOV preference	0.1 to 1%	May include dedicated lanes on streets, signal timing, etc., for buses or other high-occupancy vehicles (HOVs).	Improves vehicle operation, reduces HOV travel time, encouraging increased auto occupancy if time savings are substantial.
	Traffic engineering	1 to 3% depending on base street-system condition; applies to affected streets	Broadly applicable, including techniques such as one-way streets, signal coordination, turn prohibition, and elimination of unnecessary traffic-control devices.	Improves vehicle operation by increasing average speed and reducing vehicle delay; may increase capacity.
	Parking management	3 to 6% (CBD)	Applicable in mid-sized municipalities, includes on-street bans, limited supply, off-street programs, etc.	A versatile measure can be used to improve vehicle operation, increase automobile occupancy, or discourage automobile use.
Land-use zoning and transportation planning	Integration	10-15% long-term in impacted areas	Involves the proximate location of residential, retail, and employment opportunities; extremely energy effective because short trips (cold-start) are the most energy inefficient.	Reduces the number and length of vehicle trips.
	Density	10-15% long-term in impacted areas	Employment and population density determine the level of ridesharing opportunity and transit use. Density is also related to ability to integrate activity types.	Increases transit use and reduces trip length.

area, an industrial area, an arterial street, or a single intersection.

- The time of impact may include peak hours, midday, evening, and week-ends.
- The types of trips affected may include those within communities, or those made by shoppers or school children.
- The groups affected may include automobile drivers and passengers, existing and new transit riders.
- The types of impacts include reductions in trips, shifts from auto to other modes, and changes in vehicle operations — faster traffic flow, fewer stops, etc.

Step 2: Choose applicable performance measures

When an energy-conservation program is implemented, changes will occur in the performance of the transportation system. Each of these changes can be measured and will directly affect energy consumption. The performance measures will vary among the types of actions, and all measures will not be needed for any given action.

Changes in performance and energy consumption may be estimated from before and after measurements of the following variables:

- number of trips made by mode (auto driver, auto passenger, transit passenger, other),
- trip length or distance,
- car occupancy (persons per vehicle),
- transit load factors (passenger km / vehicle km),
- travel times and / or speeds (may include stops),
- mode share.

Various combinations of these variables will produce ''performance measures'' that can be used to estimate energy changes:

- vehicle-kilometres of travel (VKT)
- vehicle-hours of travel (VHT)
- minutes per vehicle-kilometre

Step 3: Estimate ''before'' and ''after'' conditions

To evaluate the effectiveness of each conservation measure, it is essential to estimate or calculate energy consumption before implementation and to compare these data with the energy consumption expected once the conservation measure is fully implemented. The first task is to estimate the changes in transportation-system performance based on surveys of the existing (''before'') conditions and estimates or predictions of ''after'' conditions; then the corresponding energy changes are calculated.

The basic data required for these estimates include:

- number, length, and mode of trips;
- car / transit occupancies;
- vehicle fuel-consumption rates.

The data for ''before'' conditions may be obtained from available records or special surveys of speeds, occupancies, and volumes. Comparable data for ''after'' conditions can be estimated on the basis of expected changes resulting from the improvement. Chapters 2 through 7 give illustrative examples of the type of changes that can be expected.

For example, average car speeds on a given roadway may be 20 km / h during peak periods and 25 km / h during off-peak periods. It is estimated that an improved traffic-signal system will provide 40 km / h speeds. Thus, based on the design of the new signal system, there would be a gain of 20 km / h in peak periods and 15 km / h in the off-peak.

The calculations or estimates should be as accurate as possible, keeping in mind the purpose of the analysis. It is most important that the assumptions related to the changes be well-developed and reasonable and that the degree of change, its cause, and its possible evolution over time be fully understood.

Step 4: Calculate changes in energy consumption

Energy consumption for before and after conditions is calculated by applying the data collected in Step 3 to each applicable measure of effectiveness identified in Step 2, and then translating the results into energy terms. Specific guidelines are contained in the individual chapters of this Manual.

To calculate anticipated net change in energy consumption, it is necessary to add up all the energy-consumption figures for the ''after'' condition and then subtract the total energy figures for the ''before'' condition. In some cases, it may be necessary to add up the increase or decrease in transit energy, plus the increase or decrease in automobile energy; in cases where there is no change in the energy consumed by one mode, it could be excluded from the calculations. The net change in energy consumption should include both direct and indirect components — where major new construction is involved. Where operational changes are involved, only direct energy should be estimated.

Optimally, the net change should show an overall reduction. However, there may be some cases where the results will indicate an increase in energy consumption. This may be due to either the direct-energy component, the indirect-energy component, or both. The direct-energy component is the most important in that it relates directly, in most cases, to crude-oil consumption.

Examples of estimating net changes in energy are given in Appendix tables A.1 through A.5.

Step 5: Compare benefits and costs

Once the energy analysis is complete, it is necessary to compare the total net energy benefit to the total cost of the conservation measure. This procedure will make it possible to evaluate a wide range of conservation measures and to establish a priority listing of the measures that are the most cost-effective. The major steps in this analysis are outlined below.

First, it is necessary to estimate the costs required to implement the conservation measure. These costs may include the capital costs of buses, equipment, and infrastructure; the implementation costs; and the operating and maintenance costs. Each of the cost components should be converted to annualized values and added to arrive at a total annual cost. In some cases, it will be necessary to deduct the additional annual revenue generated by new transit passengers.

Second, the net annual costs per unit of energy saved should be computed. This ratio can be expressed either in terms of dollars per Megajoule or dollars per litre of fuel saved. (Gasoline and diesel fuel can be considered separately.)

It is also possible to estimate the net costs of the measure by subtracting the annual cost of the energy saved from the net annual cost of the conservation measure.

Once this analysis is complete, those measures that are the most cost-effective should be assessed for their other impacts and, where feasible, considered for implementation.

Table 10.4 gives, as an example, cost-effectiveness estimates for various urban transportation actions in the United States. These estimates provide broad guidelines for the preferred improvements from an energy perspective; they are intended to complement community-specific calculations.

Corollary Impacts — The analysis of energy-conservation actions should also consider other impacts that will influence their feasibility:

- Certain projects may save little energy, but will produce other important benefits (for example, redesign of a high-accident-location intersection).
- Some projects may not be feasible from the aspect of practical workability. For example, eliminating parking on a business street where merchants have no other parking available; such a project may increase capacity and save time, but it could hurt merchants and would not be well accepted. Similarly, creating new arterial streets through a residential area might help traffic flow, but meet with strong community objections.
- Some projects may improve traffic flow but could increase energy consumption (for example, a new freeway extension). In these cases, non-energy considerations may take precedence, depending upon specific community objectives.

Table 10.4

Cost Effectiveness of Urban Transportation Energy-Efficiency Actions

Action	Estimated litres saved per project dollar* expended
Traffic signal optimization	79-110
Compressed work weeks	87
Signal interconnection / coordination	26-91
Ridesharing (carpooling & vanpooling)	15-64
Advanced computer control of signals	19
Flexible work hours	15
HOV priority treatments	0.8-3.0
Freeway traffic management	2-3
Area-wide express bus services	0.8
Broad transit expansion programs	0.4

SOURCE: Frederick Wagner *Energy Impacts of Urban Transportation Improvements*. Prepared for Institute of Transportation Engineers; December 1980.

* Costs in U.S. dollars

The key point is to assess the energy-conservation measures in practical terms, and to modify them as needed to assure their practicality.

3.4 Formulate Improvement Plans

Many transportation energy-improvement actions are interdependent. These should be combined into groups of actions to avoid transferring problems and to assure that the benefits of those actions are realized. This coordination of actions is essential in a Central Business District or along an arterial street. But it may also include tying together ridesharing programs, access changes, and bus-service revisions for a large suburban office centre. A park-and-ride lot for a transit or commuter rail line should be keyed to changes in transit service, parking-rate schedules, and access.

There is no formula for this coordination of projects. In practice, it relies largely on professional judgment — such an approach can be successful where public agencies work together and agree on problems and solutions.

The programming of energy-conservation actions is somewhat complex. It calls not only for establishing improvement priorities, but also for carefully coordinating energy-related actions with actions designed to improve transportation service. When a common action achieves both objectives, plan and program development is straightforward. But where energy and mobility improve-

ments conflict (as occasionally might occur), tradeoffs or compromises may be needed.

Improvement programs should contain a coordinated set of actions that are keyed to an area's needs and resources. Within a specified 5-year time frame, priorities should be established for a 1st year, 2nd-3rd years, and 4th-5th years.

Priorities should consider:

- budget,
- community acceptance,
- the severity of the problem,
- the amount of benefits and size of population benefitted,
- the relation of the improvement to the major movement system.

Improvements that are "necessities" should be favoured over those that are niceties. More specifically, the staging sequence should favour actions that:

- solve today's problems,
- alleviate major transportation system constraints,
- avoid transferring problems,
- save as much transportation energy as possible,
- can be afforded by the community.

Within this context, each stage should provide a reasonable distribution of improvements, in terms of costs and geography.

Setting priorities is, at least in part, a political process — both for energy and transportation actions. Professional judgment, affordability, and community preferences will continue to be important. The key is to identify problems and solutions, test their effectiveness and energy savings, and then organize preferred solutions into appropriate groups and programs.

Appendix

Table A.1

Evaluating Direct Energy Savings for Transit Changes

Change in automobile travel (modal shift to transit)

$$\Delta ADE = \frac{(TR_b - TR_a) \times FAP \times ATL}{AO} \times AFC$$

Annual transit ridership before (TR_b)	100 000
Annual transit ridership after (TR_a)	150 000
Former automobile passengers (FAP)	80%
Automobile trip length (ATL)	2 km
Automobile fuel consumption rate (AFC)	15 L gasoline/100 km
Automobile occupancy (AO)	1.5

$$\text{Change in auto direct energy, } \Delta ADE = \frac{(100\ 000 - 150\ 000 \times 0.8 \times 2)}{1.5} \times \frac{15}{100}$$

$$= -8000$$

Therefore, the change in auto direct energy is a decrease (a plus sign would denote an increase) of 8000 L of gasoline per year or 8000 × 34.66 MJ/L* = 277 280 MJ per year.

Change in bus travel

$$\Delta BDE = (BT_a - BT_b) \times BFC$$

Annual bus travel before (BT_b)	50 000 km
Annual bus travel after (BT_a)	40 000 km
Bus fuel consumption rate (BFC)	50 L diesel/100 km

$$\text{Change in bus direct energy, } \Delta BDE = (40\ 000 - 50\ 000) \times \frac{50}{100}$$

$$= -5000$$

Therefore, the change in bus direct energy is a decrease of 5000 L of diesel fuel per year or 5000 × 38.68 MJ/L* = 193 400 MJ per year.

Change in bus fuel efficiency

$$\Delta BDE = BT \times (BFC_a - BFC_b)$$

Annual bus travel (BT)	100 000 km
Bus fuel consumption rate before (BFC_b)	50 L diesel/100 km
Bus fuel consumption rate after (BFC_a)	45 L diesel/100 km

$$\text{Change in bus direct energy, } \Delta BDE = 100\ 000 \times \left(\frac{45}{100} - \frac{50}{100}\right)$$

$$= -5000$$

Therefore, the change in bus direct energy is a decrease of 5000 L of diesel fuel per year or 500 × 38.68 MJ/L* = 193 400 MJ per year.

Table A. 1 (continued)

Conversion of buses to alternative fuel

$$\Delta BDE = BT \times (BEC_a - BEC_b)$$

Annual bus travel (BT)	50 000 km
Bus energy consumption before (BEC_b)	8.3 MJ/km* (24 L gasoline/100 km)
Bus energy consumption after (BEC_a)	6.7 MJ/km* (26 L propane/100 km)

Change in bus direct energy, $\Delta BDE = 50\ 000 \times (6.7 - 8.3)$

$= -80\ 000$

Therefore, the change in bus direct energy is a decrease of 80 000 MJ per year or an increase of 13 000 L of propane per year to save 12 000 L of gasoline per year.

*Conversion factors for the energy forms used in this example are: crude oil, 38.51 MJ/L; diesel fuel, 38.68 MJ/L; motor gasoline, 34.66 MJ/L; electricity, 3.60 MJ/kWh; propane, 25.6 MJ/L; natural gas, 37.23 MJ/m^3; heating oil, 38.68 MJ/L (*Ontario Energy Review*, 2nd ed. Ontario Ministry of Energy; March 1981. 49 pp.).

Table A.2

Simplified Procedure to Estimate Approximate Energy Consumption in Urban Areas

$$\textit{Daily fuel consumption* (in litres)} = \frac{[100.4(D) + 0.63(T)] \times (N)}{1000}$$

where D = total travel distance in kilometres, T = system travel time per vehicle in seconds†, N = number of vehicles. Total city fuel consumption is calculated by summing fuel consumed over all city streets as illustrated below.

Arterial streets

A. 40 km with an AADT‡ of 24 000 and an average operating speed of 50 km/h (total travel time 2880 s)

Fuel consumption (per day) $= \frac{[100.4(40) + 0.63(2880)] \times (24\ 000)}{1000}$

$= 139\ 930\text{L}$

B. 80 km with an AADT of 20 000 and an average operating speed of 40 km/h (total travel time 7200 s)

Fuel consumption (per day) $= \frac{[100.4(80) + 0.63(7200)] \times (20\ 000)}{1000}$

$= 251\ 360\ \text{L}$

C. 40 km with an AADT of 15 000 and an average operating speed of 30 km/h (total travel time 4799 s)

Fuel consumption (per day) $= \frac{[100.4(40) + 0.63(4799)] \times (15\ 000)}{1000}$

$= 105\ 590\ \text{L}$

Collector streets

80 km with an AADT of 10 000 and an average operating speed of 25 km/h (total travel time 11 520 s)

Fuel consumption (per day) $= \frac{[100.4(80) + 0.63(11\ 520)] \times (10\ 000)}{1000}$

$= 152\ 896\ \text{L}$

Local streets

200 km with an AADT of 1800 and an average operating speed of 25 km/h (total travel time 14 400 s)

Fuel consumption (per day) $= \frac{[100.4(200) + 0.63(14\ 400)] \times (1800)}{1000}$

$= 52\ 473\ \text{L}$

Total daily fuel consumption = 702 249 L

SOURCE: *Analytical Procedures for Estimating Changes in Travel Demand and Fuel Consumption*. In, Urban Transportation Energy Conservation, Volume II, prepared for U.S. DOE; October 1979.

*Not applicable to average speeds over 60 km/h. The equation is based on a weighted composite of vehicles (1976) by weight class.

†Travel time is the value calculated by dividing system travel distance by average speed.

‡AADT, average annual daily traffic (number of vehicles).

Table A.3

Estimate of Fuel-Consumption Changes with Signal Coordination

$$\textit{Daily fuel consumption* (in litres)} = \frac{[100.4(D) + 0.63(T)] \times (N)}{1000}$$

where D = total distance travelled in kilometres, T = system travel time in seconds†, N = number of vehicles per day.

Example

Arterial 5 km in length with 4 lanes, no parking, 15 intersections
Carries 24 000 vehicles/day
Average travel time prior to improvements = 560 s (32 km/h)
Assumed improvement in travel time = 15%
Resulting travel time = 476 s (36.8 km/h)

Base condition

$$\text{Fuel consumption} = \frac{[100.4(5) + 0.63(560)] \times (24\ 000)}{1000}$$

$$= 20\ 515 \text{ L/day}$$

After condition (interconnected signals with optimized timings)

$$\text{Fuel consumption} = \frac{[100.4(5) + 0.63(476)] \times (24\ 000)}{1000}$$

$$= 19\ 245 \text{ L/day}$$

Reduction in fuel consumption = 1270 L/day or 6.1% along the arterial

SOURCE: *Analytical Procedures for Estimating Changes in Travel Demand and Fuel Consumption*. In, Urban Transportation Energy Conservation, Volume II, prepared for U.S. DOE; October 1979.

*Not applicable for speeds greater than 60 km/h.

†Travel time is the value calculated by dividing system travel distance by average speed.

Table A.4

Example of Carpool Formation and Calculation of Energy Saved

Use 2-person carpool rule on a 10-km freeway HOV lane.

Present number of carpools, C_0	1000
Travel time in non-HOV lanes, t_g	15 min
Travel time in HOV lane, t_s	10 min

e is a parameter developed through observation.
e = 0.05 to 1.6 for 2-plus carpool rule (use of 1.0 is generally satisfactory for first estimate).

Using the following equation, the number of carpools after HOV measure (C_1) can be calculated.

$$C_1 = C_0\left(1 + e\left(\frac{t_g - t_s}{t_g}\right)\right)$$

$$C_1 = 1000\left(1 + 1.0\left(\frac{15 - 10}{15}\right)\right)$$

$$= 1000\,(1 + 1.0\,(1/3))$$

$$= 1333$$

or an increase of 333 carpools.

If 333 new carpools were formed, the energy saving calculation would use these factors:

- 333 new carpools assumes that 333 cars have been removed from the traffic (if it is carpools per hour, the number must be adjusted to cover the peak period)
- one-way average work-trip distance is 10 km
- 2 trips are made per day
- there are 250 working days per year
- average auto fuel consumption is 14 L/100 km or 0.14 L/km

Annual energy saving = 333 × 10 × 2 × 250 × 0.14
= 233 100 L/year

SOURCE: *Guidelines for Preferential Treatment for High Occupancy Vehicles (HOV's)*. TEMP, MTC; October, 1982.

Table A.5

Example of Energy-Consumption Calculation for Speed Change in Non-HOV Lanes

Other energy factors to be considered are changes in fuel consumption by non-HOVs due to higher or lower speeds. Fuel consumption in the lower speed ranges (below 100 km/h) can be estimated using the formula

$$f = 0.10 + 0.0235t$$

where f = fuel consumption per vehicle (L/km) and t = mean travel time rate (min/km).

Non-HOV traffic volume	3500
Non-HOV speed before HOV lane	50 km/h
Travel time rate	1.20 min/km
Non-HOV speed after HOV lane	45 km/h
Travel time rate	1.33 min/km
Length of HOV lane	10 km

Fuel consumption per vehicle before HOV lane

$$f = 0.10 + 0.0235(1.20) = 0.12820 \text{ L/km}$$

Fuel consumption per vehicle after HOV lane

$$f = 0.10 + 0.0235(1.33) = 0.13133 \text{ L/km}$$

Difference = 0.00313 L/km

Annual increase in non-HOV fuel consumption (assuming 2 trips per day and 250 working days per year)
= 0.00313 × 10 × 2 × 250 × 3500
= 55 000 L/year

Table A.6

Specific Conditions of Applicability

Conservation Measures	Land use and environment	Transportation
Demand management		
Staggered work hours	Employment density — 7000 jobs or more / square kilometre with mix of activities and employers Employment of 10 000-15 000 in single-purpose activity (government, manufacturing) or corporate office park	
Flex-time	Large, single-agency employer, with over 750-1000 employees	Available transit service during off-peak periods desirable
Shorter work week	Large, single-purpose employer with 750-1000 employees	Available transit service during off-peak periods desirable
Employer ridesharing program	Major employers with 350-500 or more employees at given location for carpool, 1000 or more for vanpool	Limited transit service in corridor Less than 20% of peak-hour trips by transit Travel distances over 10 kilometres Congestion on surrounding roads (i.e., roads operate at Service Level D or E)
Area licenses	Need to reduce VKT 38 000 auto destinations / km^2, or 58 000 employees / km^2 75% transit modal split to area in peak; express transit service available Existing car speeds in area under 15-25 in peak Bypass routes available for through traffic Congestion on approaches to centre Limited off-street parking supply	
Peak-hour parking surcharge	Need to reduce VKT to improve air quality / reduce energy consumption / increase transit ridership 38 000 auto destination / km^2 or 60 000 employees / km^2	75% modal split to area in peak period Express transit service available Existing car speeds in area under 16-24 km / h in peak period Licensing scheme not physically possible Street congestion / any capacity constraints because of inadequate bypass routes 75-80% of off-street parking spaces occupied by 9:00 a.m. On-street parking prohibited, with intensified enforcement Limited off-street parking supply
Auto-restricted zone	Employment density — 12 000 jobs / km^2 Major pedestrian concentrations Need to reduce VKT to improve air quality / reduce energy consumption / increase transit ridership Commercial or retail frontage	High transit use — over 75% of trips to area at peak; 50% mid-day (for area-wide restriction) Suitable streets around area for auto traffic Ability to maintain service and access to adjacent properties No parking garages in area (access available from other streets)
Area-wide carpools	Need to reduce VKT to improve air quality / reduce energy consumption Energy limitations and constraints Employers with less than 250 persons dispersing	Limited transit service in region

Table A.6 (continued)

Conservation Measures	Land use and Environment	Transportation
Demand management (cont.)		
Expand off-street parking supply	Major retail / commercial centres or express transit stations Major hospital / medical complex Expected increase in floor space / employment / activity Parking viewed as catalyst to CBD revitalization or commercial expansion	Less than 25% peak-hour trips to centre or area by transit Does not significantly compete with existing transit on principal street approaches No major queues on principal street approaches Inadequate existing supply — as measured by existing off-street facilities operating at over 85% of capacity — or facilities poorly located with respect to major driver destinations Replace on-street parking which is eliminated. *Note*: No effort to restrict auto use
Reduce parking supply	Need to reduce VKT and / or improve air quality / reduce energy consumption / increase transit ridership Energy limitations and constraints Major office / employment centre — over 38 000 jobs / km^2	High transit use — over 75% modal split to area in off-peak Express transit service available — with capacity for future growth Congestion on approach to city centre — at street capacity constraints Need to eliminate on-street parking *Note*: In conjunction with private car restrictions
Parking price priorities for HOVs	Need to reduce VKT and / or improve air quality / reduce energy consumption / increase transit ridership Energy limitations and constraints Employment of over 8000 jobs / km^2	Municipal or public-owned garages 75-80% of spaces occupied by 10:00 a.m. *Note*: Expected benefits: $5 / car / week savings — 3 min. walking time savings Apply in conjunction with measures that give HOV toll discounts, priority-lane access, and increased rates for all-day parking for low-occupancy cars.
Street-system efficiency		
On-street parking restrictions	Major commercial centres in conjunction with overall policy to improve air quality Non-residential or commercial land-use frontage Low-density development along high-speed suburban roads	Two-way streets less than 8 m in width (one-side restrictions) One-way streets less than 6 m in width (two-sides) Volumes exceed 400 vehicles / lane / m CBDs; 500-600 veh. / lane in other areas Speeds are less than 25 km / h in centres; 30 km / h elsewhere Essential curb access can be provided by other means / places. Essential curb parking can be provided at nearby locations. Heavy transit use
Peak-hour parking restrictions	Major arterial	Peak-hour volumes exceed 400 veh. / lane / h, CBDs; 500-600 veh. / lane, other areas. Speeds are less than 25 km / h in centres; 30 km / h elsewhere in peak periods. Essential access can be provided to impacted frontage. More than 12-15 buses would use curb lane in peak-hour. Curb bus lane is proposed.
Park-and-ride	Desire to reduce VKT to improve air quality / reduce energy consumption / increase transit ridership Land availability and costs — less than $1500 per space total development cost Removed from nearby residential areas Significant central area employment Low residential density in surrounding areas Generally 13-16 km from CBD	Limited pedestrian and bus traffic in tributary area Road capacity constraints on approach to major centres (Service Level E) Available express transit (rail / bus) Minimum competition with or dilution of existing transit service Competitive costs and trip times to city centre — minimum 5-min. time savings Minimum service frequency of 6 buses / h in peak

Table A.6 (continued)

Conservation Measures	Land use and Environment	Transportation
Street-system efficiency (cont.)		
One-way streets	Comparable land use on both streets desirable	Parallel streets one block (180 m) or less apart Comparable width (capacity) on both streets Ability to increase number of travel lanes by using odd lanes No major transit destinations that require two-way bus flow on one street Reasonable terminal / transition areas Ability for pedestrians to cross streets safely Central areas with signals closer than 400 m, and residential streets 9 m or less in width
Reversible flow (streets / bridges)	Access to major industrial plants or special generators	65-75% of peak traffic in one direction Capacity in off-peak direction is sufficient via alternate routes Intersection or interchange channellization is not restrictive Peak speeds < 40 km / h; before change Eliminates "bottle-neck" section along overall route Transit can be routed via alternate streets in reverse direction.
Reversible lanes	Access to major industrial plants or special generators, or to plaza	60-65% of peak traffic in one direction Sufficient capacity in off-peak direction with fewer lanes Intersection channellization (marking) is not restrictive. Eliminate bottle-neck section along route. Preferably two lanes available in off-peak direction (i.e., six-lane street) Route and street width continuity. Left-turn lanes are not needed.
Traffic signal coordination		Operate signals less than 300-360 m apart urban, 790 m apart suburban / rural on same street — on common cycle length, preferably interconnected. Provide master control, arterial or system, where varying flow patterns exist by time of day (computer, pre-timed). Install signals when they conform to warrants set forth in Manual on Uniform Traffic Control Devices.
Priority Bus Access to Freeways		10-15 buses peak hour Two min. per bus saved. 400 to 600 passengers Freeway operates at 35 km / h or faster beyond entry point. Restricting general traffic reduces flows upstream of bottle-neck. Ramp reduces distance travelled for buses or provides essential entry to terminal, bridge, or tunnel.
Normal Flow Curb Bus Lanes (Critical)		Two or more lanes available in same direction Ability to maintain adequate delivery and service access to properties 300 daily buses 30-40 peak-hour buses 1200-1600 peak-hour passengers No curb parking Curb lanes along main business streets, 20-30 peak-hour buses Lane adjacent to curb may be used where curb parking violations are frequent.

Table A.6 (continued)

Conservation Measures	Land use and Environment	Transportation
Street-system efficiency (cont.) Contra-flow bus lanes (arterial)		*Street normally one-way* : Left turns across lane are not a problem. Provisions for pedestrian refuge at key locations *Extended section* : 400 daily buses 40 to 60 peak-hour buses 1600 to 2400 peak-hour passengers At least two lanes in opposite direction Signals 150 m apart, or more Parking prohibited Maintain service and delivery access to property. *Short section* : Necessary to maintain bus-route continuity or service to major generator 200 daily buses 20 to 30 peak-hour buses desirable 800 to 1000 passengers peak hour
Median bus lane		Two adjacent lanes available for traffic in same direction (avoid single-lane operations) Ability to prohibit left turns on two-way streets (or effectively separate conflicts from buses) Adequate width for passenger loading / unloading where provided 600 buses daily 60 to 90 peak-hour buses 2400 to 3600 peak-hour passengers
Bus-only streets	Commercial frontage Part of central area circulation or development plan	Ability to transition traffic at end points Available alternative traffic routes for through traffic and for access to the area Maintain service, deliveries, and access to adjacent properties. No parking garage entrances or exits along section 200 daily buses 20 to 30 peak-hour buses 800 to 1200 passengers (peak hour)
Pedestrian malls	Commercial (preferably retail frontage) Near ''100%'' pedestrian corner Desire to reduce VKT to improve air quality / reduce energy consumption / increase transit ridership	Present sidewalks operate at Service Level D or E (sidewalks narrow / overcrowded) Major pedestrian / vehicular conflicts along streets Heavy pedestrian flows — over 15 000/day, suburban areas; 1 500/h 30 000/day, CBD; 3 000/h Ability to route traffic around area Ability to maintain essential services Necessary to maintain continuity of major pedestrian movement
Elevated or underground walks	Employment density 13 000/19 000 jobs/km^2 Major activities exist at level of walk (i.e., office buildings — plazas above grade, subway terminals, concourses below grade) Connect transportation terminal with major generators	Heavy pedestrian / vehicular conflicts Inadequate storage capacity on sidewalk adjacent to transit station Inability to provide mid-block pedestrian crossing or traffic signal Peak-hour pedestrian volumes of over 2000-2500 (CBD); 1000-1500 elsewhere Maintain pedestrian movement continuity at given elevation.

Table A.6 (continued)

Conservation Measures	Land use and Environment	Transportation
Street-system efficiency (cont.)		
Taxi Lanes/Cruising Restrictions	Over 19 000 jobs/km^2 Desire to reduce VKT to improve air quality	Taxis represent more than 20% of traffic in stream. High concentration of taxis Traffic speeds less than 15 km/h For taxi lanes — 100-150 taxis/h
Grade separation (fly over/under)	Minimum land and property taking	Inadequate intersection capacity after traffic engineering improvements Restrictive capacity point on both streets Heavy turning movements and/or multi-phase signal controls Over 60 000 intersecting vehicles/day Adequate approach distances and width to prevent transferring congestion
Add left-turn lanes		1. *Left-turn lanes without widening (paint)* Street width allows an odd number of lanes (10, 15, 20 metres) (Minimum average lane width should be: 2.5-3 metres left-turn lanes, 3 metres - other lanes) Ability to remove parking on approach to intersection to provide minimum 1:20 transition for through lanes (urban); 1:30 taper (rural) Less than 15% commercial vehicle traffic Operating speeds in through lanes are over 65 km/h (rural, outer suburbs) 2. *Left-turn lanes without widening (physical channellization)* Existing median strip 4-4.5 metres or wider 3. *Left-turn lanes — with widening* Street width does not allow left-turn lane unless through lanes are reduced; and traffic flows do not warrant reducing through lanes Street operates at Service Level D or above (urban, inner suburbs) Three accidents/year over five-year period attributable to left turns (urban, inner suburbs) 150-180 left turns in peak hour (urban, inner suburbs) Need to provide special signal phase for left turns Operating speeds in through lanes over 65 km/h (rural) *Note*: Generally similar guidelines used for right turns — general goal is to *add* lanes without reducing through-lane capacity.
Left-turn phasing		Left turns over 150-180 in peak hour Three or more through lanes in opposing direction; or two or more through lanes in opposing direction with speeds over 65 km/h Ability to segregate left turn in one or more lanes Three accidents/year over five-year period attributable to left turns (urban, inner suburbs)
Prohibit left turns	Central or commercial business districts	Left-turn volume exceeds 20% of approaches Not possible to provide special left-turn lane or signal phasing (inadequate widths) Street operates at Service Level D or above No gaps in opposing traffic stream at unsignallized intersections during peak periods Alterntive routes available to accomplish movement Conflicts with heavy pedestrian flows (i.e., over 1000 pedestrians/h)

Table A.6 (continued)

Conservation Measures	Land use and Environment	Transportation
Street-system efficiency (cont.) Prohibit left turns (cont.)		More than three accidents/year involving turning movements Intersection of two major arterials *Notes*: Restrictions can be for one or both peak periods, 7 a.m. to 7 p.m., or for 24 hours. Buses can be exempt from turn restrictions. Somewhat similar conditions apply for right turns; major factors are inadequate radius, pedestrian-vehicular conflicts.
Two-way left turns	Suburban strip development	Continuous left-turn demand for both directions Adequate widths for five-lane operations (or seven-lane operations) Congestion due to left-turning demand Cross streets 400 m or more apart
Improving transit efficiency Expand bus service	800 to 1600 persons/km^2 — minimum density — regular route service	0.9-km coverage — 1500 persons/km^2 or more, 90% of residents 0.8-km coverage — 770-1500 persons/km^2, 50-75% of coverage Provide service within 3-km radius of park-and-ride facility 20-25 passengers/bus hour, weekdays Does not compete with existing services — (exception: may relieve overcrowded rail lines)
Bus loading/off-street turn-around	Land available with minimum dislocation Low-and medium-density areas (turn-around) Regional shopping centre Street system at end of line not conducive to turning buses around without excessive conflicts or added distance travelled Inadequate driver comfort facilities at end-of-line	
Bus loading terminals	Land available with minimum dislocation Locations within walking distance of major passenger destinations and transit lines More than 30 000 jobs in central area (central terminal)	Limited capacity to load and unload buses along curb On-street routing slow, unattractive, and unreliable Heavy traffic volumes and street congestion in surrounding areas Large volumes of express or low-frequency buses Route structure does not require through service 20-25 peak-hour terminating buses with more than 1000 passengers Terminus or major interchange station along rail transit line Terminal will not increase fleet requirements or operating costs
Bus shelters	Hospitals, schools, elderly housing centres ''Downtown'' stops All stops with 200 or more boarding or transferring passengers daily — non-CBD All stops with 300 or more boarding or transferring passengers daily — CBD	

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